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ELEMENTS
OF
RAILWAY SIGNALING

SUPERSEDES HANDBOOK 50

GENERAL RAILWAY SIGNAL
A UNIT OF GENERAL SIGNAL

A3055

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PREFACE

In 1954, the material contained in this pamphlet was published, in commemoration of the 50th Anniversary of our Company, to help signalmen get a better understanding of signaling systems, of their principles of operation and how these principles are applied.

These principles still apply today and, for this reason, the material contained in the original publication (Handbook 50) is reproduced herein to provide a valuable reference for those persons new to the signaling field.

General Railway Signal Company

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TRACK CIRCUITS

NON-CODED

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FUNDAMENTALS OF D-C. TRACK CIRCUITS

"Perhaps no single invention in the history of the development of railway transportation has contributed more toward safety and dispatch in that field than the track circuit. By this invention, simple in itself, the foundation was obtained for the development of practically every one of the intricate systems of railway block signaling in use today wherein the train is, under all conditions, continuously active in maintaining its own protection.

"In other words, the track circuit is today the only medium recognized as fundamentally safe by experts in railway signaling whereby a train or any part thereof may retain continuous and direct control of a block signal while occupying any portion of the track guarded by the signal."

These paragraphs are quoted from the Third Annual Report of the Block Signal and Train Control Commission, dated November 22, 1910, thirty-eight years after Dr. William Robinson patented the closed circuit track circuit. The track circuit is still fundamental to most of our signaling systems. There are many different arrangements of the track circuit in use today, but they are all alike in their basic principle of operation.

A track circuit in its simplest form is an insulated section of track with a relay on one end and a battery, or some other source of energy, on the other end.

Figure 101 shows an elementary track circuit. It consists of:

1. A source of energy—in this example, a battery.
2. A limiting resistance, so called because it limits the current from the battery.
3. Rails and rail bonding, both offering resistance.
4. Ties and ballast, both offering a path for current leakage from rail to rail. This path has resistance, spoken of as "ballast resistance."

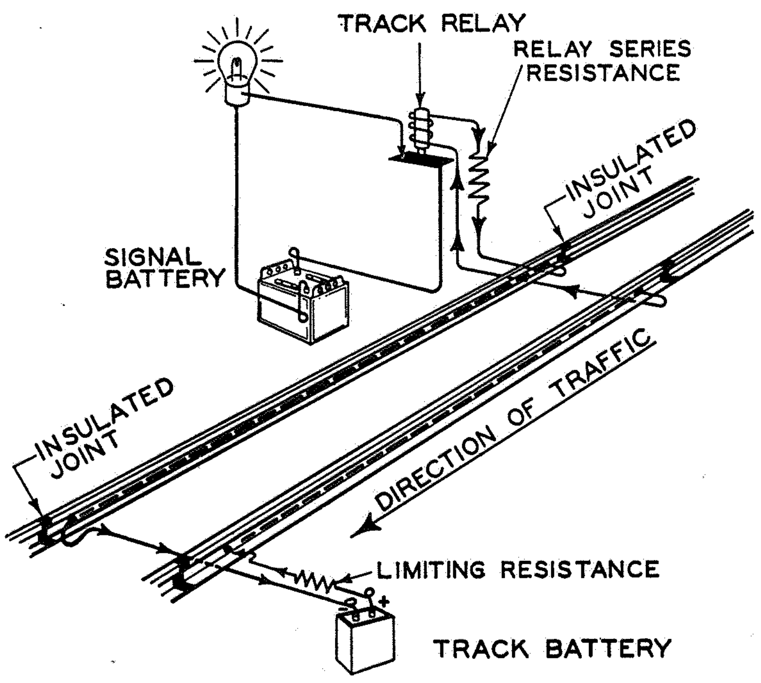


Figure 101. Diagrammatic track circuit.

5. Relay series resistance (resistance placed in series with the relay). This has come into use only in recent years.
6. A track relay.

The arrows show the direction of current flow. Starting from the positive post of the battery, current flows through the limiting resistance, the one rail, through the relay winding, the relay series resistance, and back through the other rail to the negative post of the battery. With the relay thus energized, it closes a contact to light the lamp (or to control a signal mechanism to its proceed aspect).

As the wheels and axles of a train move onto the track circuit, Figure 102, they provide a path from rail to rail through which the battery current flows, thus robbing the relay of its current and causing it to open the contact through which energy is feeding to the lamp (or to control a signal mechanism to its stop aspect).

Underlying this simple concept are many factors that make the track circuit a complicated problem. Figure 103 shows the track circuit as a network of resistances: rail resistance, ballast resistance, limiting resistance, and relay resistance. In an average track circuit, the resistance of the rails may vary from 0.015 to 0.04 ohm per 1000 feet of track. The ballast resistance may vary from one to hundreds of ohms per 1000 feet of track. A 4000-foot circuit may have, for example, a total rail resistance of 0.1 ohm and a total minimum ballast resistance of 0.25 ohm in wet weather. In dry weather, or in zero weather, this ballast resistance increases to hundreds of ohms.

Where there is multiple track, the complexities of the resistance network increase. Figure 104 shows the network at a 4-track location. If we have a ballast resistance of one quarter ohm here, each rail to ground is but one eighth ohm—and only one quarter ohm from any one rail to any other rail. It should be noted, however, that individual track circuit currents stay remarkably well in their sections because of the relatively high conductivity of the rails.

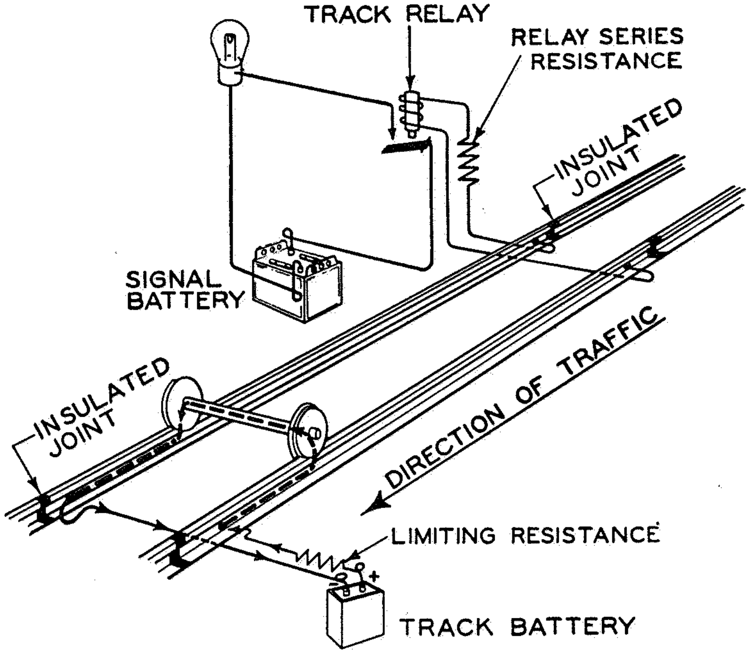


Figure 102. Diagrammatic track circuit, occupied.

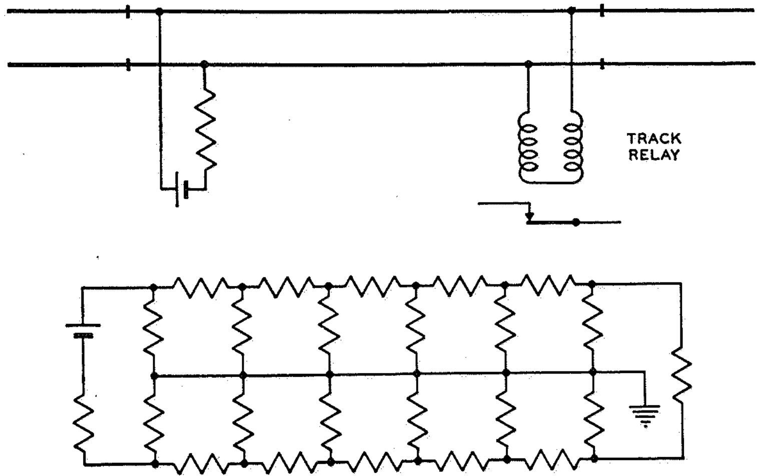


Figure 103. A track circuit and its representative resistance network.

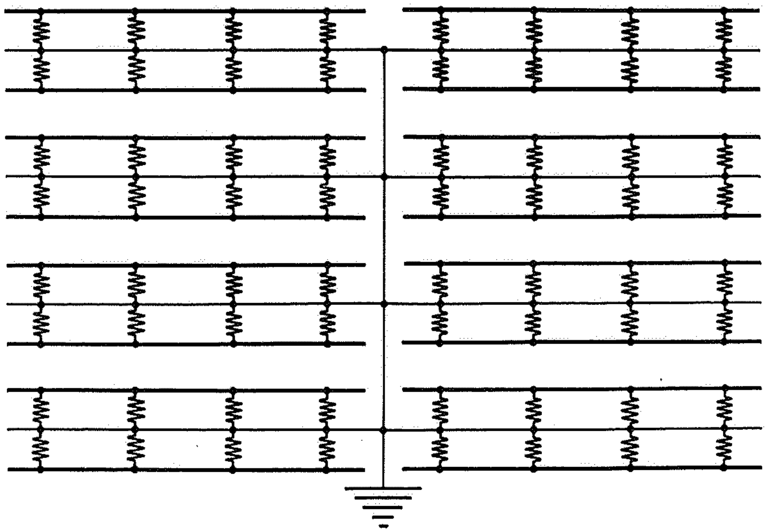


Figure 104. Representative resistance network of a four-track location.

Compared to power supply circuits, track circuits seem to have very poor transmission characteristics. Yet, they do have one great advantage over power lines—nearly zero impedance to ground for lightning arrester output. Assuming a low ballast of one quarter ohm, sixteen rails, as in Figure 104, provide a path of less than 0.01 ohm to ground. Even in dry weather, these track circuits have the capacity (condenser effect) of their several thousands of feet of rail to ground, which will take an induced charge from a power line without allowing the voltage to rise too high.

Because there is a limiting resistance in the battery feed to the track, the track voltage and, in turn, the relay voltage vary with whatever leakage path exists across the rails. This leakage path consists of the various conducting paths through the ballast and ties and, when the track is occupied, it also consists of the wheels and axles of the train. Thus we have a widely varying resistance across the rails and a widely varying voltage across the relay. A familiar analogy is the varying water pressure evident at the upstairs shower when someone is opening and closing faucets downstairs.

Figure 105 shows how relay current varies as the resistance across the rails is varied. To make our example simple, we have chosen a relay that picks up at 100 milliamperes and drops

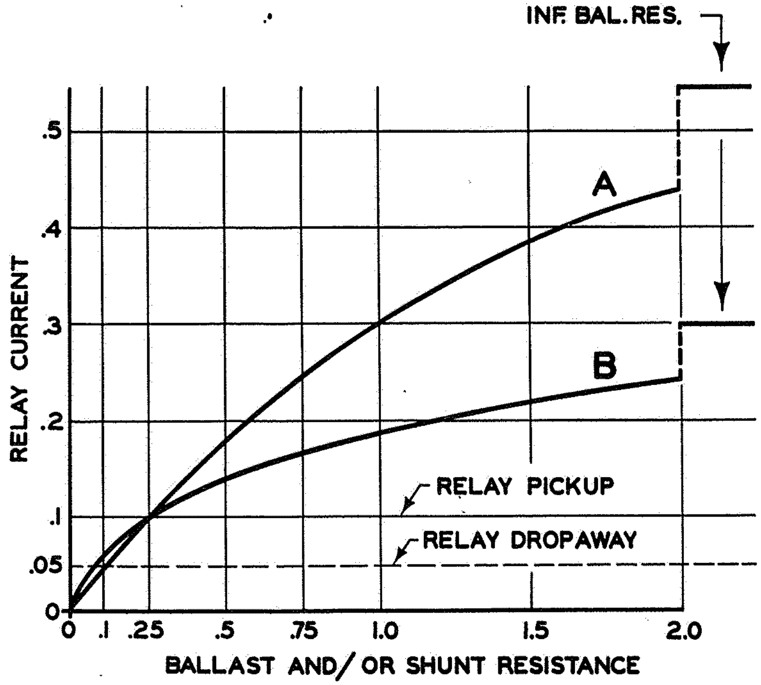


Figure 105. Relay current variation with varying resistance across the rails.

away at 50 milliamperes. By "picks up" we mean the relay is sufficiently energized to attract its armature and close its contacts with full pressure. By "drops away" we mean the relay releases its armature so that full pressure is exerted on contacts that are normally closed when the relay is not energized. These are also spoken of as "front" (closed in relay energized position) and "back" (closed in relay deenergized position) contacts. In signalman's language we would say this relay had 100 mills pickup and 50 mills dropaway—a 50 percent release relay.

Looking at curve A in Figure 105, we see that as we move from a shunt of zero resistance across the rails to a leakage of 0.25 ohm, the relay current increases to 100 mills, pickup of this relay. In other words, this circuit will not operate unless the ballast resistance is 0.25 ohm or more. Now, moving backward along curve A toward zero resistance, we find the current of this 50 percent release relay below 50 mills at 0.1 ohm. This is well above the 0.06-ohm shunt specified by the Signal Section of the Association of American Railroads to ensure the proper sensitivity of track circuit shunting.

This picture is varied by many things: percent release of the track relay, relay resistance change with temperature, "off" and "on" charge voltage of the track battery, type of battery, rail resistance changes with temperature, etc.

CIRCUIT ADJUSTMENT

Obviously, however, the end to be obtained is not to get the best shunt with the highest allowable resistance but to get the best shunt when a train enters the track circuit.

Curve A shows the conditions when we have a 4-ohm relay without added relay series resistance. Curve B shows the conditions when we add 4 ohms of series resistance to our 4-ohm relay. Incidentally, we have to reduce the limiting resistance in the track battery feed to do this, otherwise our relay will not pick up on the given 0.25-ohm minimum ballast.

In comparing the two curves we note:

1. Curve A shows relay current below dropaway at 0.1 ohm, while curve B is still well above dropaway. In fact, on curve B the dropaway point is barely reached at the A.A.R. 0.06-ohm shunt. The first reaction is that curve B is not as good as curve A, that our shunt resistance must be lower. Note now, for future reference, that when we added the 4 ohms in series with the 4-ohm relay, we doubled the interrail voltage at the release value of the relay—a point to remember when we consider ionization voltage as will be explained under "Train Shunt."
2. At infinity ballast resistance, the relay current in curve B rises to only 0.3 ampere as against 0.55 ampere for curve A. This lower current at dry ballast gives faster shunting as we shall explain under "Relay Operation."

PERCENT RELEASE OF TRACK RELAY

Suppose we substitute a track relay with a percent release approaching 100, that is, we move the "relay dropaway" line up close to the "relay pickup" line. Now our circuit will release with a quite high resistance shunt, just a little less than 0.25 ohm. The answer to a signalman's prayer? Not quite. It is possible to build a very high release relay but it requires special adjustments, special core material. Such a high percent release relay will not maintain its operating values consistently over a period of years. We expect a relay to stay in service for many, many years with little or no attention. We have seen, for example, annual relay test report cards that have indicated no change at all for 15 years. By working to a 65 percent release, we can insure maximum stability in service.

Another factor affecting the choice of relay release percentage is what we might call the sub-low minimum ballast condition of a track circuit. This condition usually occurs at the start of a shower after a long dry period. The ballast particles are coated with fine dust. At the first wetting, the dust particles are merged to form innumerable rail-to-rail paths of unusually low resistance. As the rain continues, this material washes away, and the rail-to-rail resistance rises again. A low percent release relay will be far more likely to remain picked up through such a sub-low ballast condition. Curves in Figure 105 show that, with a 65 percent release relay, the ballast could drop much lower than 0.25 ohm, that is to 0.150 ohm, and not cause the relay to drop away and suddenly place a signal at stop in the face of an approaching train without prior warning. If we had a high percent release relay, we should have to adjust the circuit for that much lower ballast resistance. The result would be an approach to the same resistance shunt, and no advantage would be gained.

One other natural phenomenon also works against the high release relay. At nominal low ballast conditions and when there have been no trains over the circuit for some time, the rails seem to settle themselves into the ballast—or something else happens, exactly what, we don't know—which also brings the ballast resistance to a sub-low and reduces the relay current below its pickup value. Under this condition, if we should momentarily shunt the relay, it would not pick up again. Fortunately, the favorable part of this phenomenon is that when a train does run over such a circuit it disturbs the rail and ballast contact and increases the ballast resistance so that the relay picks up readily when the train gets off the circuit. Here again, a high percent release relay would be of no benefit.

TRACK BATTERIES

There are four different types of cells ordinarily used for track batteries: copper-oxide zinc, carbon-zinc, lead-acid, and nickel-iron. Here are their average voltage ranges:

Type of Cell	*Voltage Range*
copper-oxide zinc	0.9 to 0.55
carbon-zinc	1.3 to 1
lead-acid	2.2 to 1.9
nickel-iron	1.5 to 1.1

As shown in Figure 105, obviously we must adjust our track circuit so that the relay will pick up at one quarter ohm ballast when our track cells are at their minimum voltage. When the cells are at their higher voltage, the circuit will operate at a lower ballast—and the shunt will have to be lower to cause the relay to drop away.

RELAY RESISTANCE

The resistance of the track relay will increase with the temperature. We must allow for plus or minus 20 percent in relay resistance as the temperature inside the relay housing varies from 150 degrees above to 30 degrees below zero. Thus when we adjusted our 4-ohm relay to operate at one quarter ohm minimum ballast resistance, we must bear in mind that it will become 4.8 ohms, with possible failure to pick up; or, in cold weather, it will become a 3.2-ohm relay, and the shunt resistance will have to be relatively lower.

RAIL RESISTANCE

On a hot day, the rails are expanded; their ends are forced together with great pressure. In zero weather, the rails contract; they pull hard against the splice-plate bolts. With either of these two conditions, rail resistance is nearly like that of solid rail, approximately 0.015 ohm per 1000 feet of track, depending, of course, on the size of the rail. In moderate temperature, the joints are not so tight. The bonds must carry the current.

Even with relatively good bonding, rail resistance of 0.03 ohm per 1000 feet of track is not unusual. Here again we must make allowances, and shunting may vary substantially.

RELAY OPERATION

A relay, as outlined in Figure 106, is an electromagnet. Contacts attached to (and insulated from) the hinged armature make contact with the back contacts when the relay is de-energized and with the front contacts when energized.

Since the armature is hinged so that it may open or close the magnetic circuit, the flux within the magnetic structure of the relay will vary with the armature position as well as with the current through the coils. Figure 107 shows how the flux density is varied by these two factors, current and armature air gap.

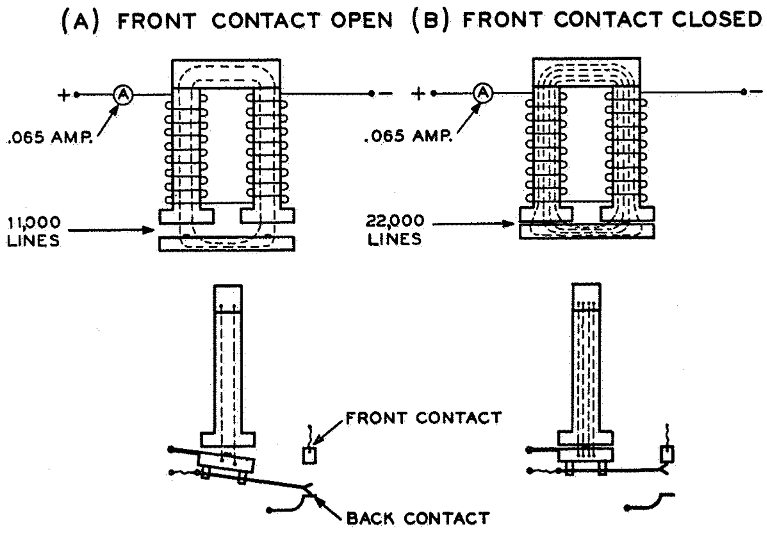


Figure 106. Diagram of relay showing how flux is varied by armature position.

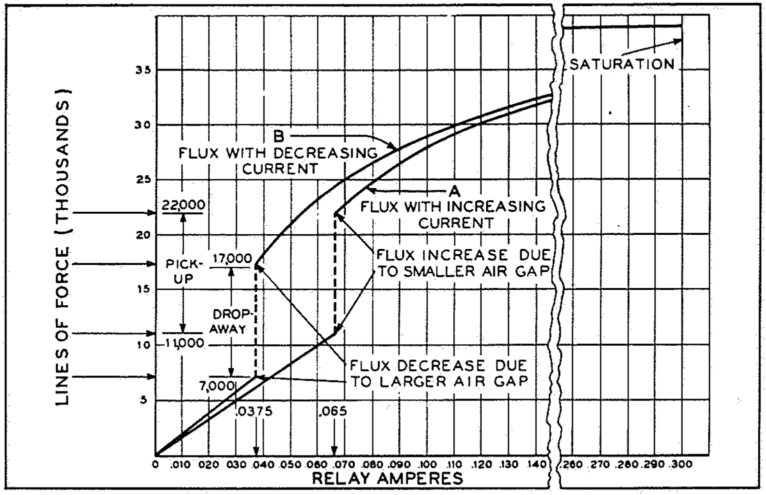


Figure 107. Curves showing how flux varies with both current and armature position.

Figure 107 is not an exact representation of the values of any particular relay. It is simply offered as a general example of this phase of relay operation.

Note that as we increase the current through the relay to 0.065 ampere, the magnetic lines of force (flux) increase to 11,000. At this point the armature is attracted to the pole pieces (the relay picks up). This reduces the reluctance of the magnetic path by reducing the air gap, and the flux increases to 22,000 lines with no change in current. As we further increase the current to 0.3 ampere, we reach the saturation point, that is, a point where further increase of current will no longer increase the flux significantly. Here the flux has increased to 38,000 lines.

Now, as we reduce the current from saturation to 0.065

ampere, curve B, we note that the flux does not decrease proportionately. We must reduce the current to 0.054 ampere to reach the same 22,000 lines. This difference of current is due to residual magnetism in the cores. To get the relay to drop away, we must further reduce the current, and in turn the flux, to 17,000 lines. This difference of 5000 lines is due to the contact friction and contact spring load curve not agreeing with torque exerted by the magnetism.

It is not our purpose here to go into more details of a relay than are necessary to show the percent release of the relay (ratio of pickup to dropaway, etc.) as these factors affect the track circuit.

We all know that when current increases in a conductor the expanding flux from that conductor in passing through a parallel conductor generates a counter or opposing voltage in that conductor. This generated voltage is proportional to the rate at which the flux passes through the conductor. Now, in a relay winding where all the turns are parallel, the expanding flux of every turn passing through all the other turns generates a counter voltage in each. Therefore, when we apply voltage to a track relay, as when a train moves off a circuit, the current and flux do not increase instantly. They increase at a rate that generates a counter voltage equal to the applied voltage. This slow pickup is desirable. On the other hand, when a train moves on to a circuit and reduces the voltage, tending to reduce the current and flux, the flux from each turn recedes back through all the other turns at a rate that will just generate a counter voltage that tends to maintain the current and, in turn, the flux. Therefore, the relay is slow in dropping away—which is not desirable.

If the relay current is just at pickup (ballast resistance at its minimum), the relay shunt is quite fast, for the flux need only recede from 22,000 lines to 17,000 lines. If the relay current were at saturation, with 38,000 lines, it would take considerably more time to drop to 17,000 lines.

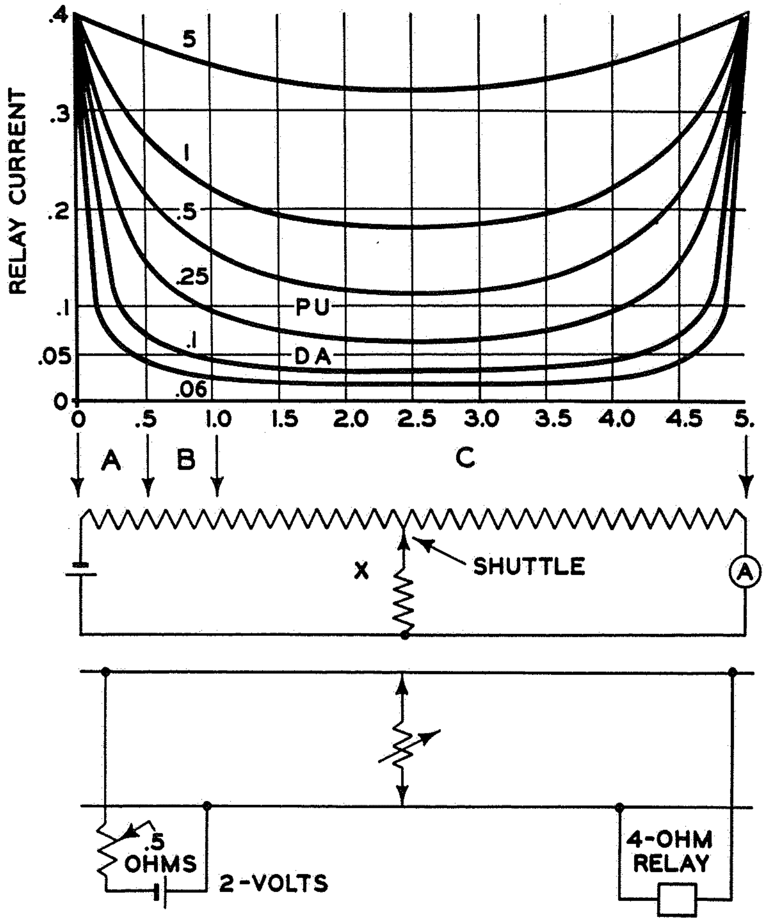


Figure 108. Curves showing how effectiveness of shunt varies with its position in the circuit.

This condition is undesirable for a short train moving from one track circuit to another. The track relay of the first circuit could pick up before the other dropped away, thus releasing route locking, for example, in an interlocking.

To avoid this condition, we put resistance in series with the relay. If we put 4 ohms in series with a 4-ohm relay, the flux will drop twice as fast because it must drop fast enough to maintain the current through 8 ohms in place of 4 ohms; and if we inserted 12 ohms it would drop 4 times as fast. Furthermore, adding this series resistance affects the circuit so that the relay current does not rise as high at dry ballast and therefore drops more quickly to the release point of the relay. However, if we refer to Figure 105, we note that when we add relay series resistance, we change the shape of the curve as from A to B and find that the ohmic shunt is poorer.

Figure 108 shows a slide type resistor, arranged as shown, with a battery and an ammeter of such low resistance that its effect on the circuit may be ignored. As shuttle X is moved from one end of the resistor to the other, the current curves plotted from the ammeter readings will be symmetrical on either side of center as shown. Repeating this procedure, using values of X from 5 to 0.06 ohm, will produce the curves shown, each labeled with the X value used.

Now let us make this slide resistor represent an unbalanced circuit, that is, a circuit where the relay resistance is much higher than the limiting resistance. Let section A, ½ ohm, represent the limiting resistance; section B, ½ ohm, the rail resistance; section C, 4 ohms, the relay; and shuttle X the ballast and shunt resistance. With this arrangement, we find the following:

1. With the travel of shuttle X restricted to section B, shuttle X (the shunt) is twice as effective on the relay end than it is on the feed end of the circuit.
2. This variation in the effectiveness of the shunt varies with the location of the rail resistance (section B) in the rest of the circuit resistance.
3. If the limiting resistance (section A) equalled the relay resistance (section C), the rail resistance (section B) could be of the same value, and yet you would have the same shunt effectiveness all along the rails.

TRAIN SHUNT

Where two conductors are in contact, a certain voltage, regardless of how small, is required to cause current to flow across the boundary. In train shunting we have this contact boundary, and in the majority of cases the voltage required is negligible. However, in many cases the rail is covered with dirt rolled into the surface or with rust from lack of use. Depending on such insulating or semi-insulating materials as may be between wheels and rails, more or less voltage will be required to break down the "film" so to speak and to establish a current path. This is termed the ionization voltage. The action is comparable to what occurs in a voltage regulation tube but, of course, we are concerned with much lower voltage.

When sufficient current is established to maintain ionization, a further attempt to raise the voltage is futile, as the ionized path simply passes more current and the added voltage is dissipated in the series resistance. In other words, with a given weight of train moving on a circuit having rails rusted to a given degree, the voltage across the rails will be of a certain value, regardless of the limiting resistance or battery voltage (assuming the voltage is at least at the ionization level).

Unusually high ionization voltage is also found in rails where no traction or braking is applied. For example, there may be a station where all trains stop by simply shutting off the power, the grade being a substitute for applying the brakes. Where this occurs, the rail surfaces tend to become glazed, as there is neither traction nor braking friction to keep them clean.

Figure 109 shows the test circuit used and the results of tests made on a side track having very rusty rails due to infrequent use. The circuit was very short and the weather dry so that there was practically no ballast leakage. A potentiometer was used so that the voltage applied to the rails could be increased from zero to whatever was needed. One truck of a car was pushed out onto the circuit, then the voltage across the rails was increased until it dropped back to practically zero.

The curves show the result. The dots on the ends of the curves show where the current flow was great enough to decompose the rust, leaving a metal-to-metal contact with practically zero resistance and a voltage and current proportional to the potentiometer setting. Inspection with a magnifying glass after the test showed the two bright metal spots.

After each test, the car was moved a few inches to a new spot. The irregularity of the wheels, rail, and degree of rust account for the variation in the curves.

The most trouble is found in little-used connections to sidings and between switches in crossovers. In such cases, we have found ionization to require more than 0.7 volt. An interrail voltage of 0.7 would put 175 mills through a 4-ohm track relay, a relay that picks up at around 65 mills. Obviously we would have to add resistance in series with the relay, at least 12 ohms, to ensure relay dropaway with this interrail voltage.

At interlockings where the track circuits are short, usually enough relay series resistance can be added. However, in some cases an additional cell of battery must also be added so that required limiting resistance can be maintained. In many cases of side track connections in long track circuits, enough relay series resistance cannot be added, and therefore a separate track circuit must be installed.

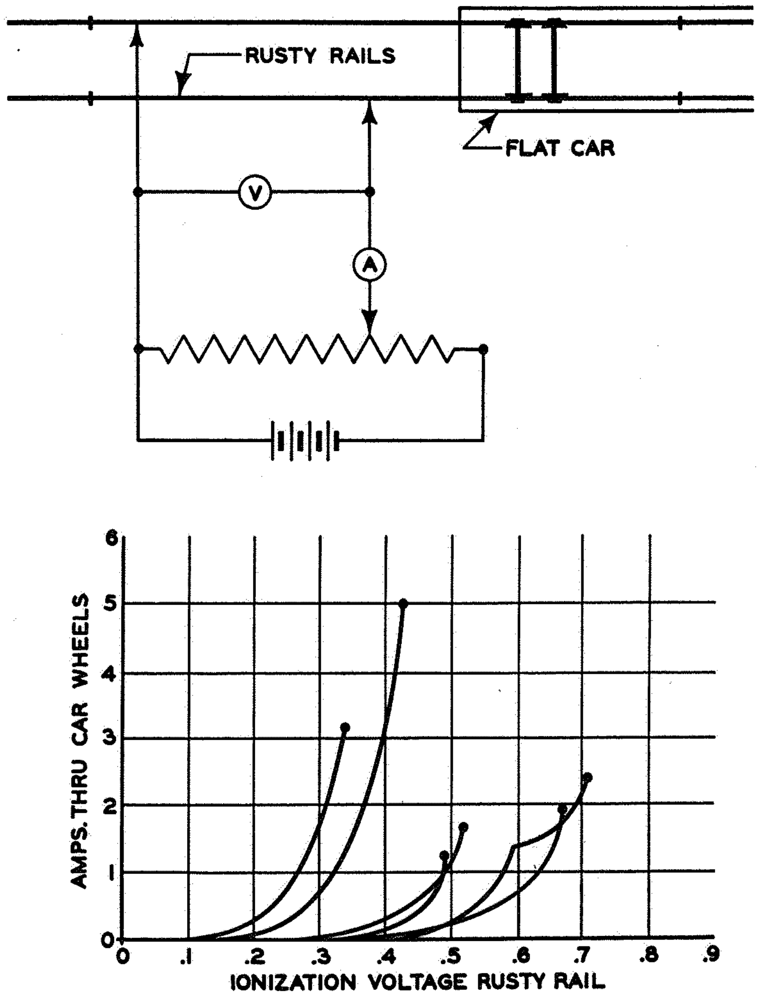


Figure 109. Test circuit and graph showing ionization voltage for test conducted on rusty rail.

Galvanic Action

With the coming of the stoker fired engines, came lower ballast resistance and tendency of track circuits not to detect broken rail. This was due to the cinders and unburned particles of coal blown from the stack landing in the ballast and creating galvanic action and in turn voltage between the rails. On a single-track road, a greater part of this material is blown clear of the ballast, but on a multiple-track road not much misses the ballast.

Where one rail has better contact with the ballast than the other, we have a good example of galvanic action. The rail making better contact with the ballast is positive, and the rail making poorer contact, as through the ties, is negative. One theory is that the ions in the ballast attack both rails, carrying the iron into the ballast and in doing so leave their extra electrons on the rails, tending to make both negative. The rail that is in contact with the ballast does not become as negative because the electrons can flow back through the ballast contact. The other rail, where this ballast contact is not present, becomes more negative, and the electrons will flow through the relay across the rails to get back to the ballast. With the presence of this stoker ash with its particles of partly burned coal and in turn sulfuric ions in the ballast, this galvanic action is greatly aggravated.

We find this same effect when we thrust one probe of a meter into the ballast and touch the other lightly to the ballast. The meter shows the buried probe to be positive. If we pull the first probe up (but do not remove it entirely) and press the other probe down into the ballast, the meter will read reversed.

A ballast-resistance network with a rail broken is shown by Figure 110. The battery end of the broken rail to ground and on to the other rail forms a voltage divider, with the relay end of the broken rail to ground in series with the relay. At near minimum ballast resistance, there is little voltage to spare, and the relay will drop. On the other hand, at near infinity ballast resistance, the resistance of the relay end of the broken rail to ground is too high to allow the relay to operate. However, there is a critical range of ballast resistance where the track voltage can affect the relay if the circuit is not properly proportioned or adjusted.

Storage-Battery Effect

The track battery charges the rails, oxidizes the positive rail, and de-oxidizes the negative rail (analogy is found in the iron negative plate of a nickel-iron battery); and this charge may operate the relay after the rail is broken. The track battery polarity also affects the result, as it either adds to the galvanic and storage-battery action or, if reversed, it tends to neutralize

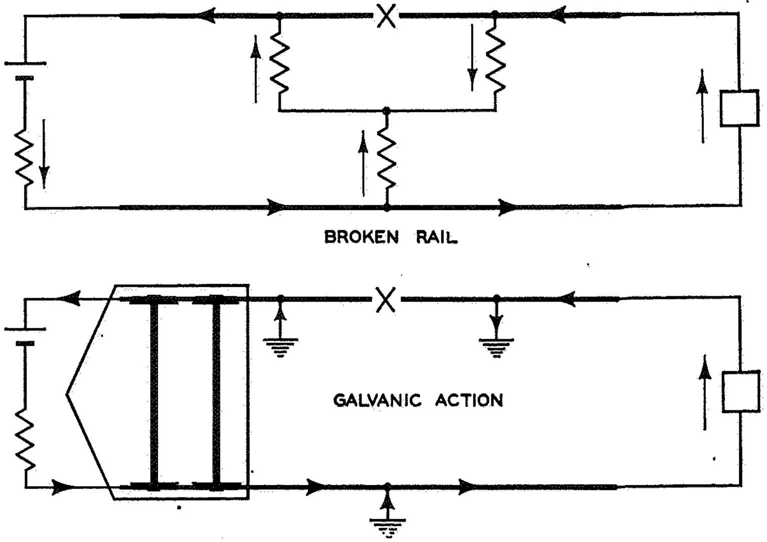


Figure 110. Possible leakage paths with broken rail (top) and with broken rail and galvanic action (bottom).

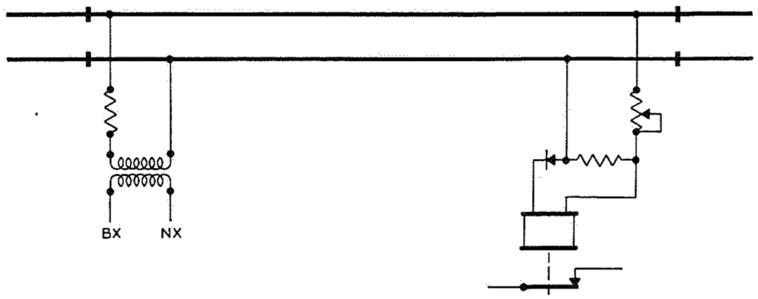


Figure 111. Half-wave rectified track circuit.

the galvanic action. However, with a train on the battery end, the battery is eliminated, as shown in lower diagram, Figure 110.

Half-Wave Rectified Circuit

This circuit, Figure 111, is energized by a.c. taken through a half-wave rectifier. Figure 112 shows how the voltage peaks during the "on" part of each cycle. These voltage peaks, 2.82 times higher than average or battery d-c. level, are thus well suited to providing proper ionization of the wheel-to-rail contact.

The half-wave circuit also has automatic regulation so that as the ballast dries out and becomes a high resistance, a condition that ordinarily makes the train shunting most adverse, the relay current is found to be not much greater than at minimum ballast.

The upper curve in Figure 112, shown dotted, represents the regulation obtained with an ordinary d-c. circuit. The lower curve, shown solid, represents regulation with a half-wave rectified circuit. Why is the regulation shown in the lower curve better? Between the impulses of the rectifier output, the induction of the relay attempts to maintain current. This induced voltage is opposite in polarity to the rectifier output and may be considered as a negative track voltage. As the ballast resistance increases, the peak track voltage also increases because there is less current flowing through the limiting resistance. However, the increased ballast resistance also

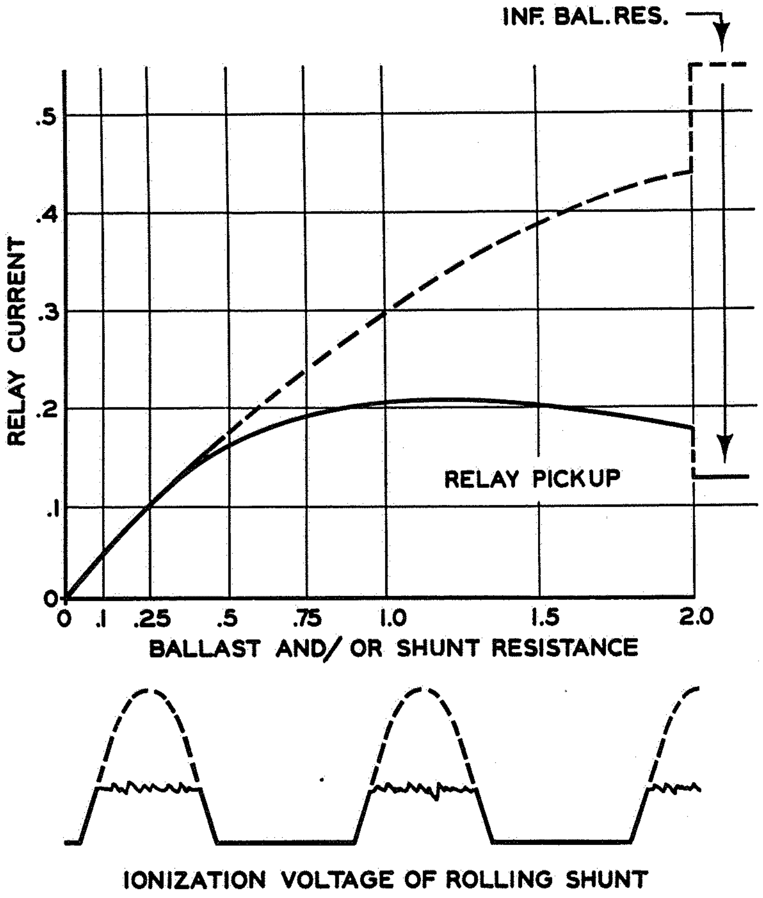


Figure 112. Regulation in half-wave rectified track circuit.

increases the resistance to the flow of the inductive relay current. This increases the negative track voltage which, when subtracted from the peak voltage, results in more uniform average track voltage and relay current. As shown in Figure 111, a bleeder resistance must be provided across the relay, otherwise, at infinity ballast resistance the relay current would drop below the operating value.

Note in Figure 112 that although the relay current is lowered from relay pickup (minimum ballast) to infinity, it is the same between relay pickup (0.1 amp.) and zero. Contrast this with the relation between curves A and B, Figure 105.

A-C. TRACK CIRCUITS AND RELAYS

ELECTRIC ROADS WITH D-C. PROPULSION

The advent of the electrified railroad, using direct current for the propulsion of electric locomotives or cars, necessitated the development of a track relay that could not be operated by propulsion return current in the track rails flowing into the relay's track winding. Direct-current track relays cannot, of course, meet this requirement.

The first alternating-current track relay was of the single-element (single-phase) vane type, taking all its energy from the rails. The first a-c. track circuits were what is known as the single-rail type, one rail being used for return of the propulsion current to the power house or substation, the other rail being broken up into track circuit sections by insulated rail joints inserted between rail ends to provide the desired length track circuit.

The single-element vane relay required a considerable amount of energy for its operation. All the energy for the relay had to be transmitted over the track rails which, due to current leakage between rails through the ballast, provide a very inefficient transmission circuit as compared to an insulated line circuit. Thus it was found necessary to limit the length of these original single-rail track circuits to about 1000 feet or less, depending on ballast conditions.

The demand for longer track circuits, up to 5000 feet or more, necessitated the development of a more efficient type of a-c. track relay than the single-element vane. This was accomplished by the design of what is known as the two-element (two-phase) a-c. track relay. This relay has two windings or circuits; one, the track element, requiring a comparatively small amount of energy from the track circuit; the other, the local element, taking a considerably greater amount of energy, of the same frequency and of a displaced phase relation, from a local a-c. source at the relay location.

ELECTRIC ROADS WITH A-C. PROPULSION

The regular a-c. track relays as used on roads employing d-c. propulsion were not considered suitable for use on a-c. track circuits on the roads employing a-c. propulsion, since, under certain conditions that could occur, they would not be immune to improper operation by the 25-cycle propulsion current. This led to the design of frequency selective types of relays both single element and two element, for operation on 60-cycle track circuits installed on roads employing 25-cycle propulsion current. The single-element relay is known as the static-frequency type and the two-element relay is called a centrifugal-frequency relay. Either of these relays will not pick up to make front contacts if 25-cycle current, due to unusual track circuit conditions, should invade its track or track and local windings. In fact, excessive amounts of 25-cycle current in the relay's windings will, due to saturation of its magnetic circuit, cause the relay to assume its deenergized position, opening its front contacts.

NON-ELECTRIFIED RAILROADS

A natural extension of the use of a-c. relays and a-c. track circuits was their application on non-electrified railroads, employing steam or other means than alternating or direct current for propulsion. Unlike d-c. relays, a-c. relays are immune to the effects of foreign d.c. Such foreign d.c. may invade the track circuit from trolley lines which parallel the railroad, a situation once quite common when trolley lines were numerous. Being d.c., it does not materially affect a-c. relays.

A-C. TRACK RELAYS

There are two general types of a-c. relays, the rotor type and the vane type.

The magnetic structure of a-c. relays is laminated, being composed of thin punchings about 0.012″ to 0.015″ thick, of a special grade of sheet steel, assembled to provide a structure of the shape and size required. Thin sheets are used in order to minimize hysteresis and eddy current losses caused by the alternating flux in the magnetic circuit. Each sheet is sometimes coated with a very thin film of varnish in order to electrically insulate adjoining sheets.

ROTOR TYPE A-C. RELAYS

This type is in principle a small induction motor arranged to operate a contact bar with contact fingers assembled thereon. Operation depends upon the effect of a rotating magnetic field produced by out-of-phase currents in the windings of the stator. Mutual attraction between the rotating stator field and the magnetic field of the currents induced in a metallic non-magnetic rotor causes the rotor to revolve and operate the contacts. The stator must have two separate windings, the currents in which must be out of phase, in order to produce a resultant rotating a-c. magnetic flux that has a time-space variation without any zero points. The maximum effect is obtained when the two currents are out of phase by 90 degrees, the ideal phase relation. This ideal relation is rarely obtained in a relay operating on a track circuit. The energy required by the relay will vary in accordance with the sine of the angle of phase displacement between the currents in the local and track phases of the track relay.

Model 2A Relay

This a-c. relay, Figure 113, was developed to provide a more efficient and more universally applicable relay than those previously used. The circular laminated slotted stator has two distributed windings, one the local, the other the track winding, which carry the out-of-phase currents to produce a rotating magnetic field.

Each winding is made up of two sections. The four leads of each are brought out to binding posts, so the sections of each winding can be connected in series or in multiple as desired in order to meet various operating conditions. A laminated steel core is located inside the stator and is separated from it by a concentric air gap. A cup-shaped metallic non-magnetic rotor, usually made of aluminum, is mounted on a shaft and is free to rotate in the air gap.

The stator's rotating magnetic field flows between the stator and core across the air gap and through the aluminum rotor, inducing eddy currents therein. The attraction between the stator's rotating field and the magnetic field of the eddy currents in the rotor causes the rotor to revolve.

The motor structure, comprising stator, core and rotor, is enclosed in a cast iron compartment. The rotor shaft extends through a small hole in this compartment into the contact chamber of the relay. A pinion on the end of the shaft meshes with a sector, which, in turn, is connected by a link to the contact bar. The sector is counterweighted to produce a counter torque to drive the sector and contact bar to their down positions when current is removed from the relay's track winding.

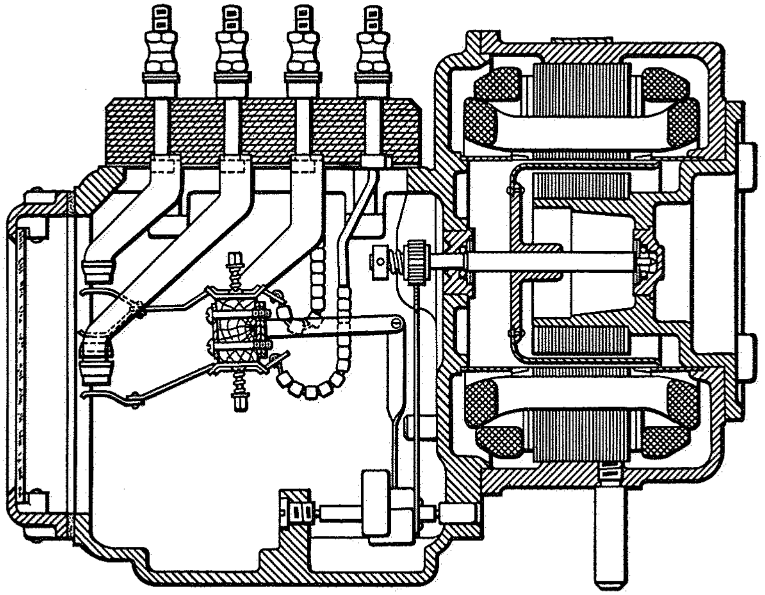


Figure 113. Model 2A alternating current relay.

The Model 2A relay is the most efficient a-c. track relay available. It has been made up in various assemblies and modifications to meet required conditions, such as a 4-way and a 6-way relay. It is available with ordinary operating time—0.32 second to open front contacts—for use on long track circuits in automatic signal territory; or as a quick-acting relay—0.15 second to open front contacts—for use on relatively short—about 1500 feet or shorter—detector track circuits at interlockings and in subways, where a relay that shunts and picks up fast is required. The Model 2A is available as a two-position or as a three-position relay and also as a frequency selective relay.

Frequency Selective Track Relays

The a-c. track relays ordinarily used for track circuits on non-electrified or d-c. electrified railroads are not suitable for track circuit use on railroads employing a-c. for propulsion purposes, since they would operate on the propulsion current if, due to unusual conditions that may occur, the propulsion current should invade the local and track windings of the track relay to a sufficient degree.

Such undesirable conditions can occur due to a broken rail, high resistance bonding between the track rails, or to a cross between the a-c. propulsion power line and the signal power line.

The frequency selective type of track relay was developed to provide a track relay that would operate only on currents in track and local windings having a frequency different from that of the propulsion current. Since railroads in the U. S. A. use 25-cycle current for propulsion purposes, the frequency selective relays were designed to operate on 60 cycles and to be immune to operation by the 25-cycle propulsion current. Note the 60-cycle frequency of the signal current is not an integral multiple of the third harmonic of the 25-cycle frequency of the propulsion current.

Two frequency selective track relays, both of the rotor type and modifications of the Model 2A regular track relay, have been developed by G-R-S, the Model 2A centrifugal frequency track relay and the Model 2A static frequency track relay.

Model 2A Centrifugal Frequency Track Relay

This relay is shown in Figure 114. It is a 2-element, 2-position relay with a stator having two separate distributed windings, an inner core, and an aluminum rotor that revolves in the air gap between the stator and the inner core. The method of transmitting the driving force due to rotation of the rotor to the contact bar is, however, quite different from the pinion-and-sector method used in rotor type relays that are not

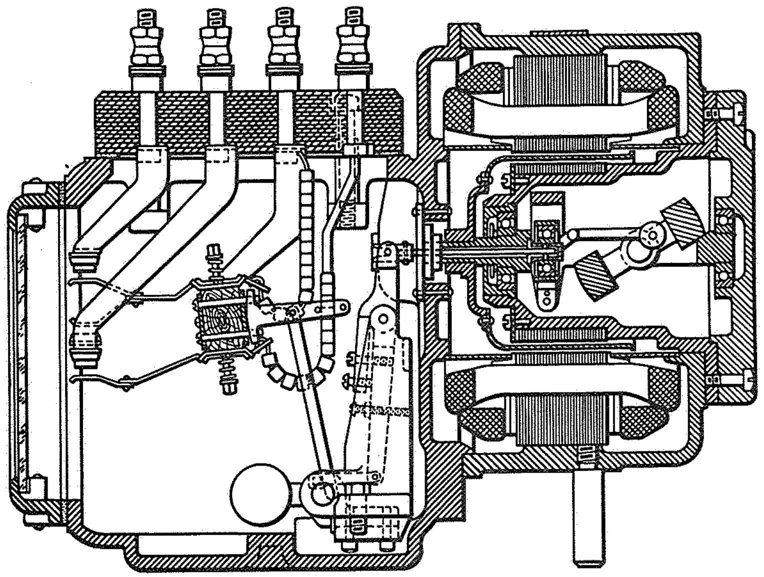


Figure 114. Model 2A centrifugal frequency track relay.

specifically designed to be frequency selective.

When the track section is not occupied, the rotor revolves at a speed proportional to the frequency of the signaling current. At this speed, a centrifuge—a sort of fly-ball mechanical governor which is connected to the rotor—operates the contacts. If the track is shunted or if the rotor is running at a speed lower than that corresponding to the signaling frequency, the centrifuge does not operate the contacts.

Model 2A Static Frequency Track Relay

This relay is shown in Figure 115. It is a single-element, 2-position relay made frequency selective for operation on 60-cycle current. It will not operate on 25-cycle propulsion current. It has a stator with two separate windings. The inner core and rotor are similar to these parts used in the non-selective Model 2A track relay. The frequency selective character of this relay is obtained by the use of a Wheatstone bridge arrangement of reactances and resistances interposed between the leads from the track circuit and two distributed stator windings.

The bridge assembly unit is mounted in the relay's contact chamber. Due to the space required by this unit, a 6-way relay case must be used to handle four front contacts. This relay has no centrifuge, the contact bar being operated from the rotor shaft through pinion, sector and link connection the same as in the non-selective Model 2A track relay.

Since the static frequency relay operates as a single-element

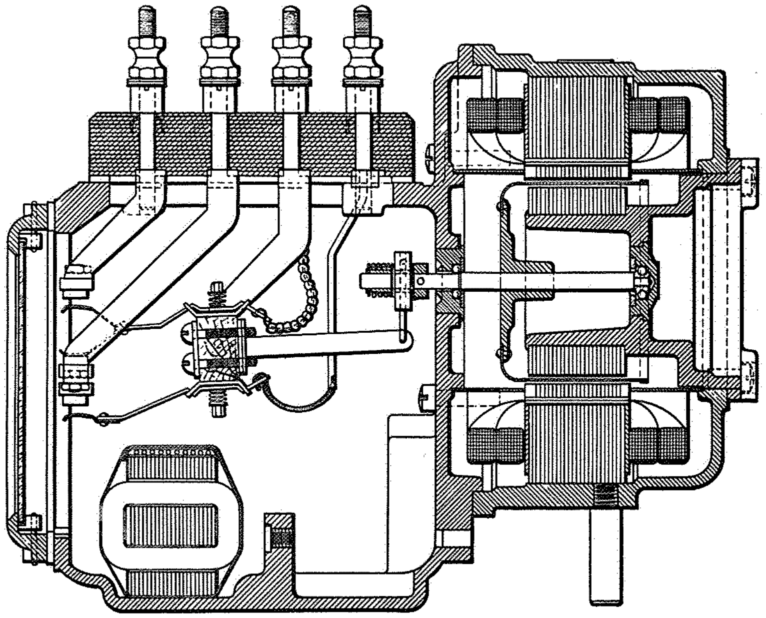


Figure 115. Model 2A static frequency track relay.

relay, i.e., takes all its energy from the track, and also because of the Wheatstone bridge unit inserted between the track and the relay's windings, it requires considerable energy for its operation. Thus its use is limited to relatively short track circuits—1000 feet in length or shorter—such as detector track circuits at interlockings.

VANE TYPE RELAYS

Operating parts of the vane relay are assembled in either a circular or rectangular enclosure with glass sides. All working parts are visible.

The method of transmitting movement or driving torque from the vane to the contact bar is from a short crank arm on the vane shaft through a link to a crank arm on the contact bar. This is designated as a direct connection as compared with the pinion and sector connection between rotor shaft and contact bar used in the rotor type relays.

There are two general classes of vane relays, single-element and 2-element.

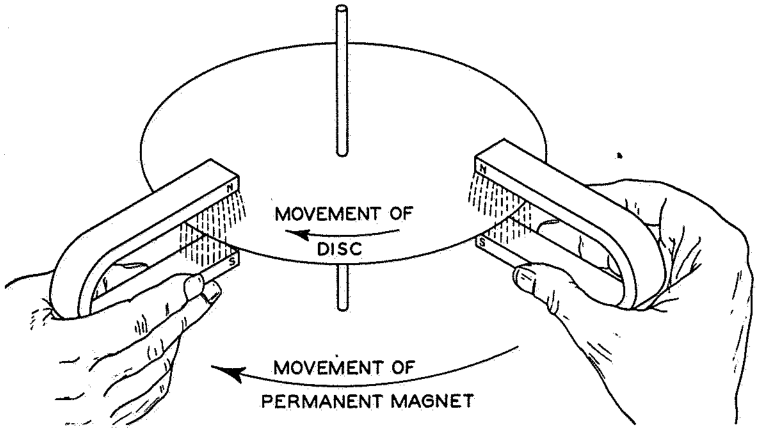


Figure 116. Theory of operation of vane relay.

Principles of Operation of Vane Type Relays

Figure 116 demonstrates the theory of operation of the vane relay. A circular copper disc with a shaft through the center is supported so that it is free to rotate. If a permanent magnet is rotated about the disc shaft in such a way that the magnetic lines of force cut through and across the disc, it will start to rotate, at a slightly slower speed, in the same direction as the permanent magnet.

Figure 117 shows an enlarged view of a section of the disc showing what takes place. When the permanent magnet is rotated, the magnetic lines of force pass through the disc and produce a voltage between two points on the disc. An eddy current flows between these points and back to its origin by the shortest path.

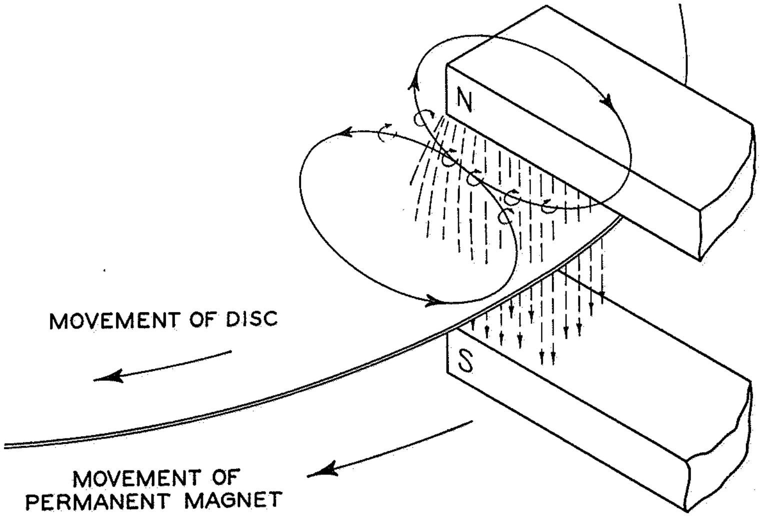


Figure 117. Eddy currents in disc and resultant magnetic forces.

These eddy currents produce miniature magnetic lines of force, which on reacting with the magnetic lines of force of the permanent magnet, establish a linkage to produce rotation.

Single-Element Vane Relay Operation

Now we have seen how we could move a non-ferrous disc—or a vane—by moving a permanent magnet.

In an a-c. vane relay, we keep the magnet stationary and move the vane by forces set up by the interaction of magnetic fluxes.

Figure 118 shows the operating element of a single-element vane relay. Flux from the electromagnet passes through the vane and sets up a circulating eddy current in the vane. Normally, the center of this eddy would coincide with the center of the pole face. However, there is a copper ferrule or shading band around half of each pole face. The flux acting on the ferrule induces a circulating current in the ferrule. This circulating current sets up a flux to oppose the flux which originally induced the current in the ferrule. Thus the ferrule flux distorts the main flux. The distorted main flux induces a circulating eddy current in the vane. Thus we have two circulating currents, both circulating in the same direction, in parallel planes, but not concentric.

Conductors carrying currents in the same direction attract each other; hence the vane moves to position its circulating eddy current so that it will be concentric with the circulating current in the ferrule. The distorted flux continues to induce other circulating currents in the same place shown by the dotted path in Figure 118, and the vane is moved upward to operate contacts as required.

Double-Element Vane Relay Operation

In the double-element vane relay, two electromagnetic structures are used, one on either side of the vane. The electromagnets are constantly energized while the relay is picked up, but the magnetism produced by one of the electromagnets lags in time with respect to the other. The reaction on the vane of the two independent magnetisms, which are out of step, produces rotation, the same as that produced by the moving permanent magnet in Figure 116.

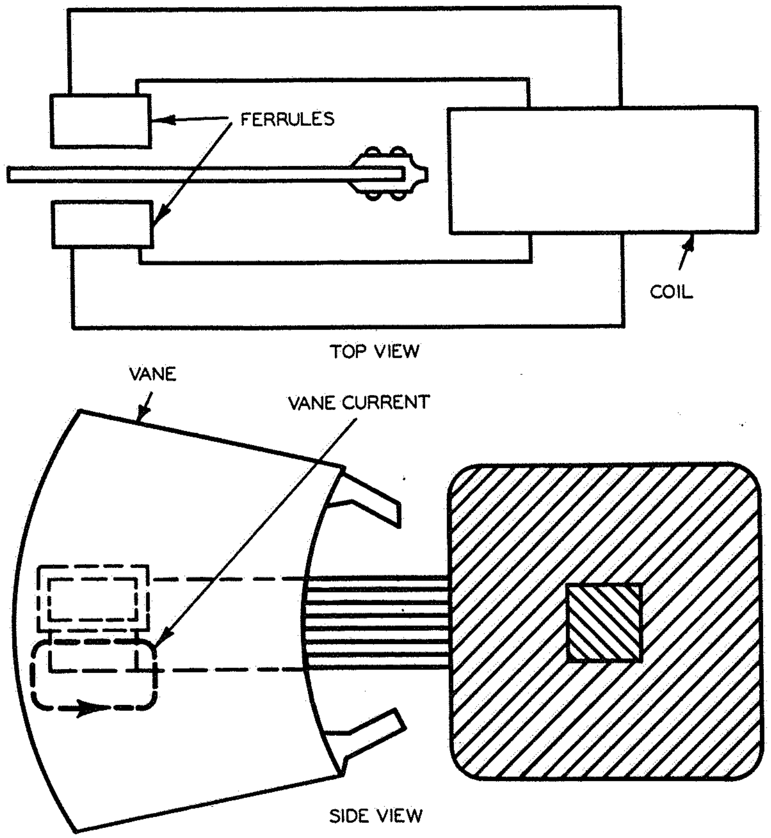


Figure 118. Theory of operation of single-element vane relay.

Figure 119 shows a complete cycle of local and track currents plotted with the track current lagging the local current. Reference lines A, B, C, etc., divide up the complete alternating current cycle into eighths, and the small figures represent instantaneous pictures or "snapshots" of what is happening in the magnetic circuit of the relay at these particular instances.

At A and A′ the local current is at a positive maximum value, the track current is zero. The local winding is producing all the magnetic lines of force and their paths are shown by the dotted lines. Notice the solid arrow (which is accentuated merely for reference and not because the lines of force are concentrated in that particular path). Compare the position of this arrow in the "snapshots" and see how IT MOVES ACROSS THE WHOLE LENGTH OF THE AIR GAP, cutting through and across the vane, much the same as the magnetic lines of force of the permanent magnet in Figure 116. All the other arrows do the same. Here, then, is the counterpart of the moving permanent magnet, only in this case the magnetic structures are stationary and THE ALTERNATING CURRENT PRODUCES THE MAGNETIC FLUX MOTION.

The direction of movement of the vane depends upon the relative instantaneous polarities of the currents in the local and track coils. Reversing the energy leads to the terminals of either coil will reverse the direction of movement of the vane. Thus 2-element relays can be made 3-position.

Figure 120 shows a G-R-S Type L vane relay. These may be single or double-element relays. The double element Type L relays may be 2-position or 3-position.

Figure 121 shows a G-R-S Type B plug-in vane relay. This is the most modern type of a-c., relay. It is double-element, 2-position.

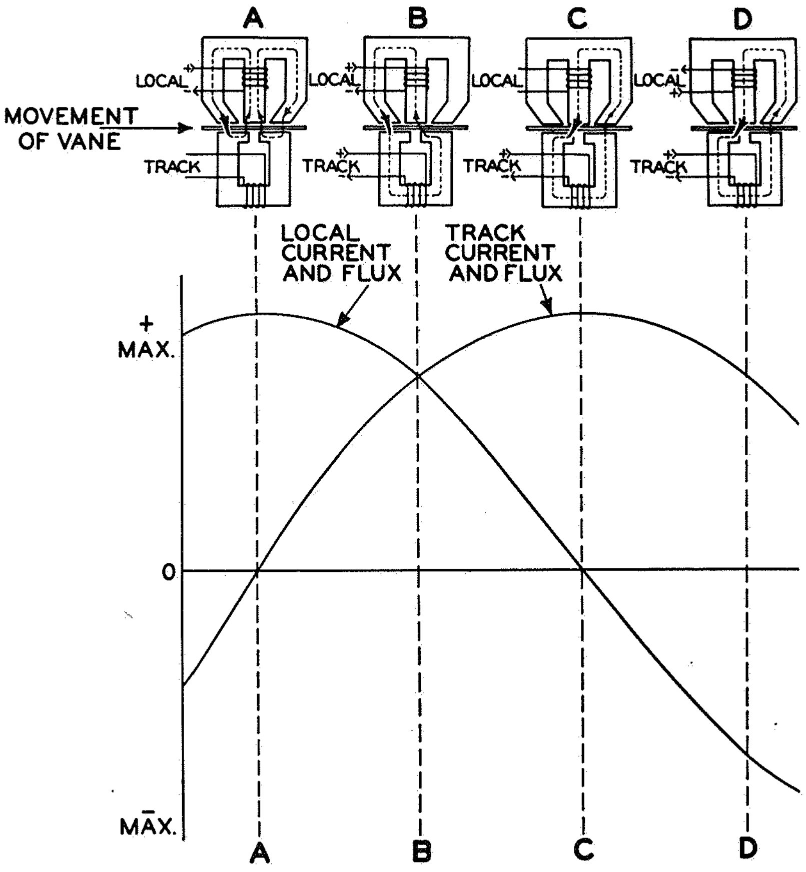
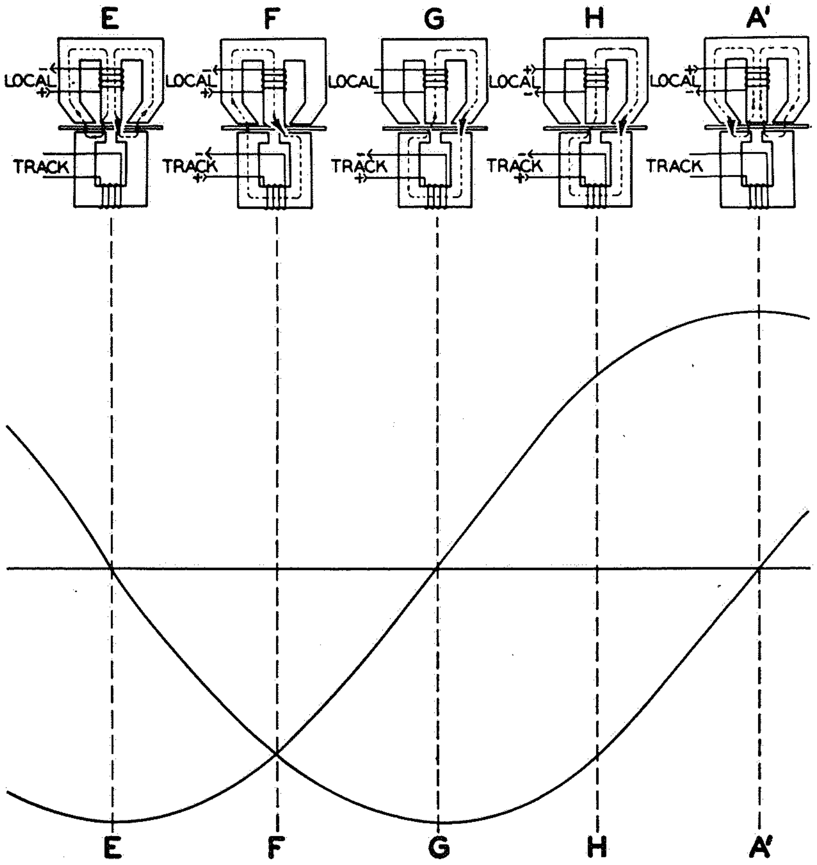


Figure 119. Theory of operation of double-element vane relay.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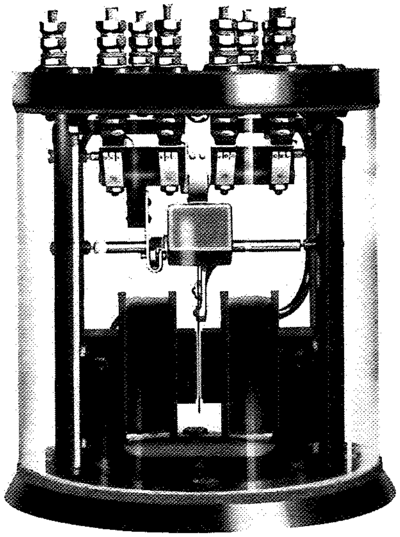

Figure 120. Type L 2-position, single-element vane relay.

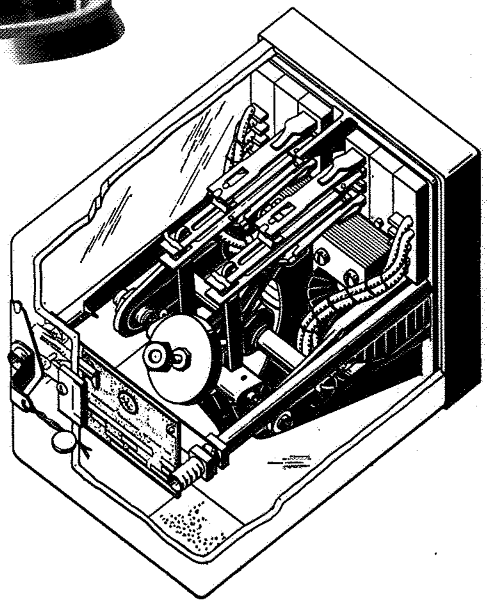

Figure 121. Type B 2-position double-element plug-in vane relay.

A-C. TRACK CIRCUITS

There are three general types of a-c. track circuits in use in North America:

1. Non-coded using a-c. track relays.
2. Non-coded using rectifiers and d-c. track relays.
3. Coded using resonant (tuned) units and d-c. track relays —for use with d-c. propulsion.

Coded a-c. track circuits are covered in the section concerning coded track circuits and will not be described here.

The general types of non-coded a-c. track circuits with a-c. track relays may be classified according to their use on railroads as follows:

1. Track circuits on non-electrified railroads.
2. Track circuits on d-c. electrified railroads.
3. Track circuits on a-c. electrified railroads.

Non-coded a-c. track circuits with rectifiers and d-c. track relays may be classified according to use as follows:

1. Track circuits on non-electrified railroads.
2. Short single-rail track circuits on d-c. electrified railroads using a balancing impedance and a combination small transformer and full-wave rectifier unit interposed between the track and a d-c. relay.

All of these general types except the single-rail rectified type can be further subdivided into the various arrangements hereinafter briefly described.

Current is usually 60 cycles although 25 cycles is used to some extent on certain railroads in Canada, on the d-c. electrified zone of the N. Y. C. Railroad between Harmon on the Hudson Division and the Grand Central Terminal, and on certain subways in the U. S. A. Fifty-cycle current for signal systems and track circuits is generally used in foreign countries.

TRACK CIRCUIT APPARATUS USED WITH NON-CODED A-C. TRACK CIRCUITS

Track transformers usually have a primary wound for 110 volts 60 cycles, or as specified, and a secondary with taps to give steps usually of about one volt to a maximum of about 12 volts. The volt-ampere capacity required for the track winding will depend on the kind of track circuit with which the winding is used. Some track transformers may have several independent track windings and, in addition, another winding to feed signal lamps, etc.

Adjustable reactors are used between track transformer and track. They are used to adjust the current to the track circuit, to limit the current when the track circuit is shunted by a train, and to aid in obtaining favorable phase relation between currents in the track and local elements.

Non-adjustable reactors are sometimes used in series with the local element of 2-element track relays to improve the phase relation between currents in the local and track phases of the relay.

Various sizes of resistors, adjustable by a slider or by taps, are used between track transformer and track in some types of track circuits both as current limiting and as phase adjusting devices.

Sometimes non-adjustable resistors are used in series with a track relay's local element in order to improve phase relation between the currents in the local and track elements.

A balancing impedance, an impedance of special design, is used across the track phase of 2-element track relays on single-rail track circuits on d-c. electrified railroads in order to prevent magnetization of the relay's magnetic circuit if any d.c. should enter the relay's track winding. The connections between the balancing impedance and the relay's track element winding are shown in Figure 125, page 123.

Fuses or Fusetrons (time-delay fuses) are used between track and transformer's secondary winding and track relay's track element on single-rail track circuits to protect the apparatus if excessive direct current should continue to flow long enough to harm the windings.

Impedance (reactor) bonds are large reactors connected between the rails at each end of double-rail track circuits on both d-c. electrified and a-c. electrified railroads. Their purpose is to permit flow of the propulsion current from one track circuit to the one adjoining while at the same time retaining the a.c. for the operation of the track relay within the limits of its particular track circuit.

The sizes of these impedance bonds are determined by the amount of propulsion return current their windings must receive continuously, or for certain specified periods, from each rail of the track circuit. The windings of these bonds are made from heavy strap copper. Referring to Figure 124, the propulsion current flows from each rail into the winding and out through the midpoint connection to the midpoint of the adjoining bond and thence out in equal amount to each rail of the adjoining track circuit, continuing in like manner through successive track circuits.

If the propulsion current is the same in each rail, the equal propulsion currents which flow in opposite directions through the two halves of the bond's windings neutralize each other, and no magnetic flux is produced in the magnetic circuit of the bond. If there is a difference between the propulsion currents in the two rails, this unbalanced current in one half of the bond will produce a flux in the magnetic circuit causing some reduction in the impedance of the bond. The decrease will depend on the amount of unbalanced propulsion current.

Since an impedance bond is connected between the rails at each end of the track circuit, a.c. will flow through it from rail to rail. Therefore, this current will be drawn from the track transformer in addition to that required for the track element of the track relay and the current drain through the track ballast. Hence the impedance of the impedance bonds should be made as high as the conditions under which they are used will permit.

POLARIZED TRACK CIRCUIT

Figure 122 shows a typical circuit with a 2-element and 3-position a-c. relay for operation on non-electrified railroads.

This type track circuit is known as a "wireless" track circuit, since it provides control direct from the track relay for operation of 3-position signals, thereby eliminating line wires and line relays.

The circuit arrangement shows a slow-release d-c. relay controlled through both a normal and a reverse contact on the track relay. The slow-release relay is required to pole change the primary of the track transformer with consequent change in the polarity of the track circuit in the rear and corresponding reversal of its track relay. The slow-release time of the d-c.

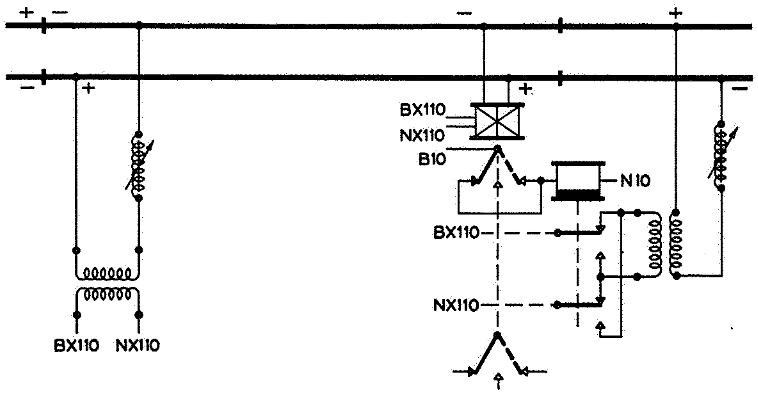

Figure 122. Polarized a-c. track circuit.

relay must be sufficient to retain its front contact while the 3-position track relay is throwing from its reverse to its normal contact or vice versa. Pole changing directly with contacts on the track relay cannot be done because of the open circuit interval occurring when the track relay reverses. This momentary removal of energy from the track would be long enough to cause the relay in the rear also to open its contacts. This condition would continue throughout the track circuits, causing what is known as "tumbledown" of all the 3-position track relays to the end of the 3-position track circuits.

TRACK CIRCUIT WITH 2-ELEMENT 2-POSITION RELAY

This track circuit, Figure 123, is a simpler, less expensive arrangement than the 3-position one, but line wires and line relays are required to control the signal. Therefore, the overall cost of the 2-position track circuit, including signal-control means, is greater than that of the 3-position track circuit.

DOUBLE-RAIL TRACK CIRCUIT FOR D-C. PROPULSION

Figure 124 shows a typical arrangement for use with d-c. propulsion. The tapped resistor is both a current limiting device and a means for obtaining the most favorable phase relationship between track and local currents in the 2-element track relay.

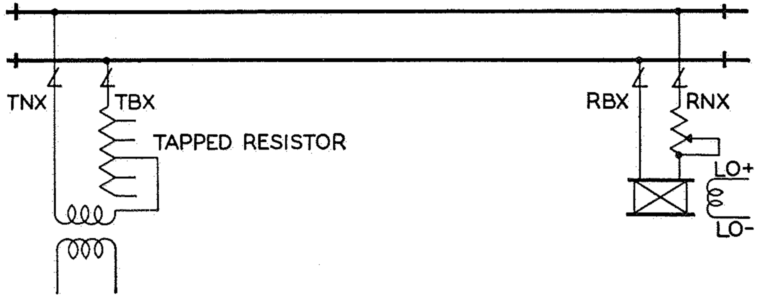

Figure 123. Track circuit with 2-element, 2-position a-c. relay.

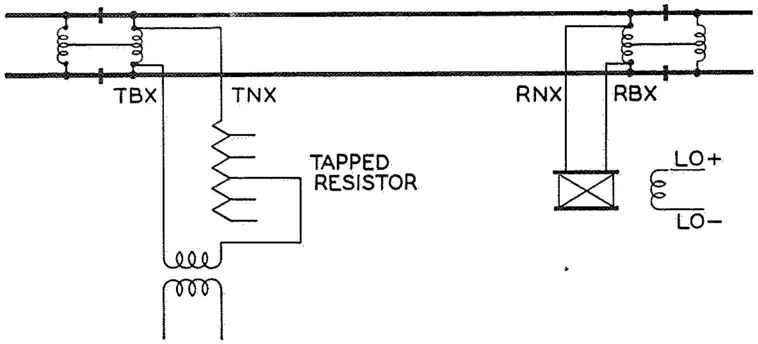

Figure 124. Track circuit with a-c. track relay and impedance bonds for d-c. (or a-c.) propulsion.

SINGLE-RAIL TRACK CIRCUIT FOR D-C. PROPULSION

This track circuit, Figure 125, requires a balancing impedance to keep d.c. from interfering with the operation of the a-c. relay.

The voltage drop of the d-c. propulsion return causes a d-c. voltage across the relay track connections. The magnitude of this d-c. voltage depends on the weight of rail, the resistance per 1000 feet of the bonded power rail, and the amount of current flow in the power rail.

The reactance of X in the balancing impedance is quite high —24 ohms at 5 volts 60 cycles, and 10.6 ohms at 5 volts 25 cycles. X has the same ohmic resistance as resistance R.

Due to the high impedance of reactance X, practically all the a.c. for operation of the relay flows through 0.67-ohm resistance R, through half section, C1, of the track element winding, and back to track, thus operating the track relay.

Taking the Model 2A 2-element track relay as an example the impedance of each half (C and C1) of the winding is approximately 1.25 ohms at 60 cycles; and the ohmic resistance is about 0.36 ohm. When there is any flow of d.c. from the track to the track element of the relay, due to the equal ohmic resistance of R and of X and the equal resistance of C and C1 of the track element's winding, the d.c. divides equally in each section of the track winding, flowing in opposite directions in the two sections. Hence, the opposed ampere turns neutralize each other, and no magnetic flux results in the magnetic circuit of the track relay.

The balancing impedance has certain limitations. One is the heating effect of the d.c. on elements R and X of the impedance and on windings C and C1 of the relay. They will stand 5 amperes d.c. continuously and intermittent short period spurts of 10 amperes d.c.

A second limitation is the saturation effect on the laminated steel magnetic circuit of the reactor by the d.c. flowing through its coil. Flux induced in the magnetic circuit by the d.c. reduces the permeability of the magnetic circuit, with corresponding reduction in the impedance of the reactance section of the balancing impedance. This permits some increase in the a-c. flow through the reactance section and its corresponding section (C) of the track element winding which opposes the a.c. in the C1 section of the track winding, thereby weakening the operation of the track relay.

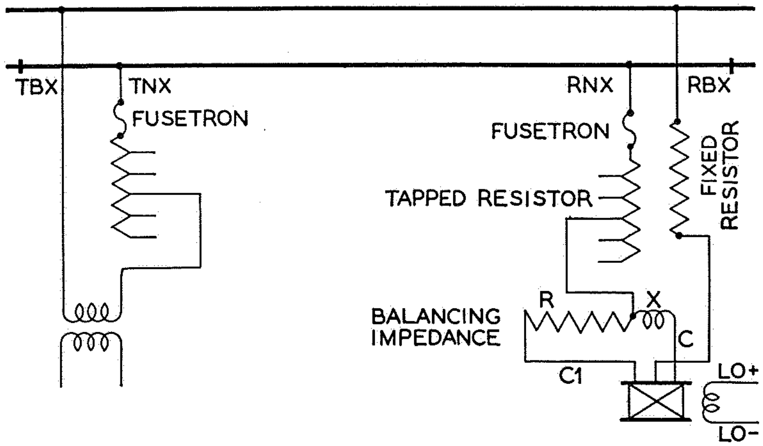

Figure 125. Single-rail track circuit for d-c. propulsion.

Tests have shown that 5 amperes d.c. from the track to the balancing impedance and track relay will require an increase of about 8% in the a.c. from the track to maintain the same strength of operation as when no d.c. is present.

Single-rail track circuits are usually used at interlockings where there are several tracks so that the power rails of the tracks can be bonded together to provide as much conductivity as possible for return of the propulsion current. They are also used extensively on subway and elevated lines.

DOUBLE-RAIL TRACK CIRCUIT FOR A-C. PROPULSION

General track circuit arrangement is similar to that for d-c. electrified railroad, Figure 124, but apparatus differs.

The track relay used must be frequency selective. Since the frequency of the propulsion current on American railroads is 25 cycles, the relay was designed to respond only to currents having a frequency of 60 cycles. When track circuits are of lengths over 1000 feet, the centrifugal frequency relay is used, and the track circuits must be double rail equipped with impedance bonds.

Impedance bonds for a-c. propulsion are smaller than those for d-c. propulsion. D-c. propulsion-return currents, especially with 600 volts, may run 750 to 1000 amperes per rail. A-c. propulsion-return currents, usually at 11,000 volts, vary from about 100 to 600 amperes per rail.

Trouble due to unbalance, i.e., difference between propulsion-return currents in the two rails, does not affect the impedance bonds to anywhere near the degree that it may on d-c. electrified railroads. This is due not only to the propulsion-return currents being smaller, but also due to the autotransformer action of the bond. If more current starts to flow through one half of the bond's winding, it induces a voltage in the other half tending to pull a larger current from the other rail through that half. Hence the bonds are not likely to be unbalanced, and therefore they do not need as large an air gap in their magnetic circuit and can be adjusted to have somewhat higher impedance than bonds used on d-c. electrified railroads.

SINGLE-RAIL TRACK CIRCUITS FOR A-C. PROPULSION

Static frequency relays may be used on short detector track circuits through interlockings where fast shunting is required, as the static frequency relay shunts faster than the centrifugal frequency relay.

It is preferable to use a centrifugal frequency relay on single-rail track circuits, however, whenever possible, since it is then possible to use more resistance in series with the leads from track to track transformer and track element of the centrifugal frequency relay to keep a-c. propulsion current out of the track element. Static frequency relays take all their energy from the track and, because of their frequency selective design, require considerable current for operation. Hence the amount of limiting resistance used in series with track leads is considerably less than can be used with centrifugal frequency relays. It is therefore more difficult to protect the static frequency relay against propulsion current.

The balancing impedance cannot be used since its principle is only effective when the propulsion is direct current.

Fusetrons are used in the track leads on single-rail track circuits to protect the track relay and track transformer against damage in case there is considerable flow of the alternating propulsion current through them. On double-rail track circuits, fuses, or preferably Fusetrons, are also used in track leads at transformer and relay, if the track leads are connected directly to rails, in order to protect against excessive flow of propulsion current through the windings in case of a broken rail or a bond cable becoming disconnected from the rail. However, if track leads are connected to terminals in the impedance bonds, as per G-R-S practice, Fusetrons are usually not used.

TRACK CIRCUIT DATA

To make calculations or laboratory tests to determine for any given type of track circuit, practical and safe operating lengths, the energy required, and the shunting sensitivity, certain data is required, as follows:

1. Ballast resistance, maximum and minimum values per 1000 feet of track.
2. Impedance per 1000 feet of track (2000 feet of rail) for various weights of rail with various types of rail bonds at frequencies of 25, 50, 60, and 100 cycles.
3. Frequency of signal current to be used.
4. Characteristics of the track relay to be used, such as: pickup, working, and dropaway currents, and time of pickup and dropaway.
5. Characteristics of the impedance bonds and other track circuit apparatus to be used.

Data on ballast resistance is either available, or ballast conditions are assumed. Tables of rail impedance are available based on tests on different weights of rail with various kinds of bonding.

TRACK CIRCUIT CALCULATIONS

Engineering calculations can be made, and vector diagrams based on these calculations can be drawn. However, in order to obtain all the data desired on the performance of a certain type of track circuit for various lengths of track circuit and over several ranges of ballast resistance, lengthy calculations involving considerable engineering time are involved.

A much faster method for obtaining this information and for checking the data obtained is to make laboratory tests on an artificial a-c. track circuit. This makes possible actual operation of the track relay under conditions that can be set up as required. Such an artificial a-c. track circuit is in use in the G-R-S Engineering Laboratory. It is constantly in use to make setups for a-c. track circuits for tests as desired and for duplicating as closely as possible actual conditions on the railroad where the track circuits will operate.

AUTOMATIC BLOCK SIGNALING

SINGLE-DIRECTION RUNNING

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    Polarized Line Control 203
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AUTOMATIC BLOCK SIGNALING SINGLE-DIRECTION RUNNING

DEFINITION

The Association of American Railroad's Standard Code defines automatic block system as: "A series of consecutive blocks governed by block signals, cab signals, or both, actuated by a train, or engine, or by certain conditions affecting the use of a block."

SIGNAL SPACING

Figure 201 shows a piece of railroad which has been divided into blocks AB, BC, and CD. The lengths of blocks are planned according to the density of traffic that is to be handled and by the braking distance of the trains. Where traffic is heavy, blocks are relatively short, in order to permit trains to follow each other closely but safely. Where traffic is light, blocks can be lengthened out.

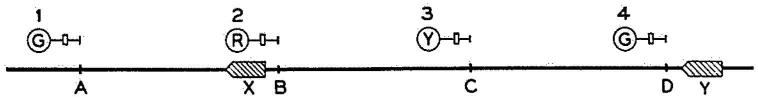

Figure 201. Diagram of 2-block, 3-aspect signaling.

For safe operation, the spacing between signals must not be less than braking distance. Braking distance means the distance it takes to stop a train which is operating at maximum permissible speed. Braking distance is a variable factor, and most railroads have conducted tests to determine what this distance is for their trains. This data is used in determining the minimum lengths of blocks. Of course, compensations must be made for grades. In actual practice, automatic block signal spacing on trunk line railroads varies anywhere from ½ mile to 2 miles; while in subways and on elevated lines, spacing may be only a few hundred feet.

You might say, "Why not space these signals so far apart that there would be no question of having sufficient braking distance?" This can be and is done in territory where there are but few trains, but in places where trains have to follow each other at short intervals, it becomes necessary to make these blocks as short as possible so as to handle the traffic.

Let us consider the simplest aspects that can be displayed by a signal system protecting this piece of railroad and their meaning to an engineman on a train. Each of these signals, 1, 2, 3, and 4, is capable of displaying a red, yellow or green light.

These aspects are defined as follows in the book of rules which govern operation of trains in automatic block territory:

Green —Proceed.
Yellow—Proceed preparing to stop at next signal.
Red —Stop; then proceed at restricted speed.

In order to see how these signals function for train operation, let us assume a train X has stopped in block AB, and a following train Y is approaching signal 4. Signal 4 is green; therefore, train Y will continue to operate at normal speed until it approaches signal 3, which will be yellow. Then the train will reduce speed so as to be able to stop when it has arrived at signal 2, which is red.

In order to keep trains moving at a high rate of speed and on closer spacing or headway, a system of 3-block, 4-aspect signaling has been developed. This system uses two signals mounted one above the other. The following are the aspects and their definitions as set forth by the AAR Standard Code:

RR—Stop; then proceed at restricted speed.
YR—Proceed preparing to stop at next signal.
YG—Proceed approaching next signal at medium speed (30 m.p.h.).
GG—Proceed.

With this system, the signals are no longer spaced braking distance apart. However, the distance from the YG aspect to the RR must be at least braking distance.

Let us take Figure 201 and modify it to a 3-block, 4-aspect system. Let us assume that in Figure 201 the signals are spaced just braking distance apart. With the aspects as given for this system, another signal can be located between each of the existing signals. With this modification, the signaling would then be as illustrated in Figure 202. (For practical purposes such a rough-and-ready method for conversion from 2-block to 3-block signaling would most likely be quite impractical, but it is used here to keep our example simple.)

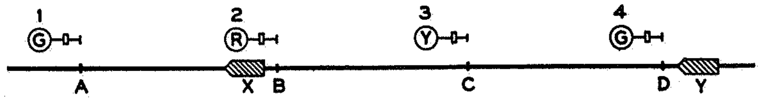

Figure 201. Diagram of 2-block, 3-aspect signaling.

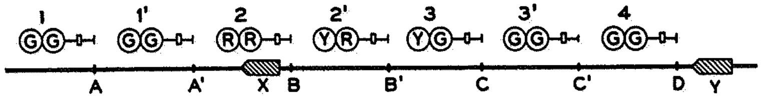

Figure 202. Diagram of 3-block, 4-aspect signaling.

Now let's assume some different conditions for trains X and Y in Figures 201 and 202 and see what the advantages of the additional signals are.

With both trains as shown, should X be standing still, Y would reduce speed at signal 3 in both figures.

If X were standing across joint A, Y in Figure 201 would have to reduce speed at signal 3, but Y in Figure 202 could continue at full speed up to signal 2′.

If X were standing just across joint B, Y in Figure 201 would have to reduce speed at signal 4, but Y in Figure 202 could continue at full speed up to signal 3′.

If the distance AB is, let us say, 7500 feet, the distance from red to green is 15,000 feet in Figure 201; but the distance from red/red to green/green in Figure 202 is only 11,250 feet—only 75% of the Figure 201 distance. Thus, if you can get 75 trains in 100 miles of the Figure 201 arrangement, you could get 75 trains in 75 miles of the Figure 202 arrangement—or 100 trains in 100 miles—a 33⅓% increase in track capacity.

CIRCUITS

Now let's see what circuits we are going to need to make this automatic block signaling work.

Starting off as simply as possible (see Figure 101 in section on d-c. track circuits) we have a very elementary arrangement where we can get 1-block, 2-aspect signaling. Quite aside from

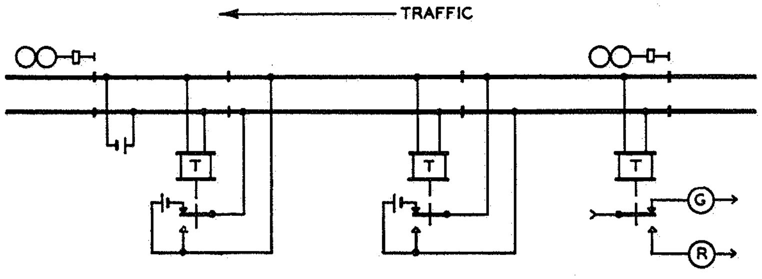

Figure 203. Use of repeating cut sections in block.

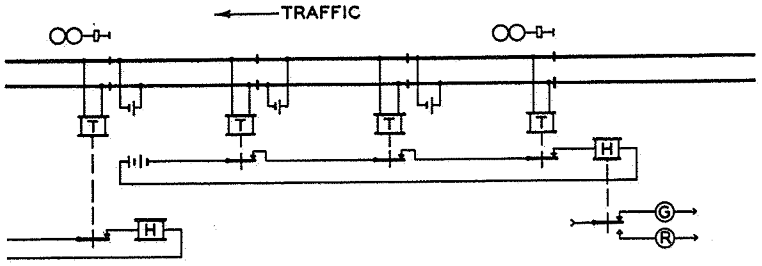

Figure 204. Use of H relay to check block occupancy.

the impracticality of having to continually creep along with our knowledge limited to just one block ahead, this arrangement has another serious disadvantage. Most blocks are of such length that it takes more than one track circuit to reach from one signal to the next. We can solve this problem in two ways. First, as shown in Figure 203, we can use repeating cut sections. Second, as shown in Figure 204, we can use as many track circuits as we need and take a pair of line wires through the block to check all the track relays.

Neutral Line Control

We can now spread our signals as far apart as we wish, but we still need additional information—"What is the position of the H relay in the next block ahead?"

Let's find this out, as shown in Figure 205, by taking another line wire back to control a distant relay, which we shall call D. Now, if we have H up, we know the block ahead is clear; (and if we have D up, we know the second block ahead is clear, so we can show a green signal). This system needs three line wires.

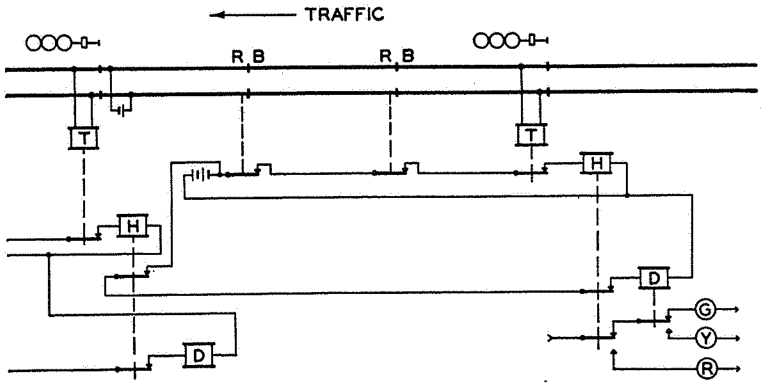

Figure 205. Simplified circuit for 2-block, 3-aspect signaling with neutral line circuit.

Polarized Line Control

The next step is to use a three-position polarized relay, thus cutting our line wire requirements to two.

Let's pause a moment here to consider the signals we are using. Thus far we have been controlling color-light signals without moving parts—with a lamp for each colored roundel.

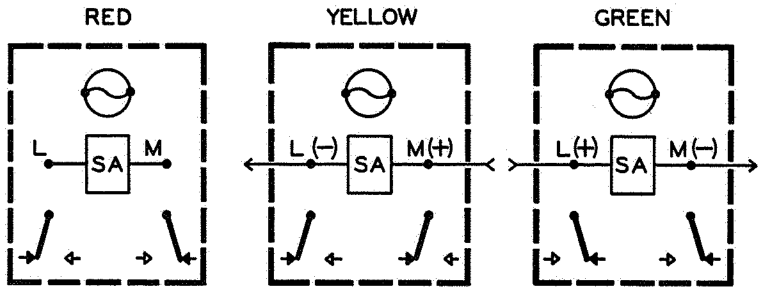

Figure 206. Type SA searchlight signal contact positions (shown facing terminal block).

Figure 206 shows how the G-R-S Type SA searchlight signal, for example, changes its aspects and contact positions in response to its control circuit. Thus we can connect a signal of this type directly to a polarized line control, and we can use its contacts to furnish a distant control for the signal in the rear.

Now let's look at Figure 207, where we have polarized line control of SA signals. This circuit does three major things.

First, it detects the condition of the track between signal 1 and 2. This is accomplished by breaking the control wires through contacts on track relays a′ and b′ and on switch circuit controller X. With any contact on a′, b′, or X open, as would be the case if a train were occupying the block between the two signals, a rail were broken, or a switch misplaced, signal 2 would display a red aspect.

Second, if signal 1 is in the stop position, relay YGP would be deenergized, causing signal 2 to display a yellow aspect

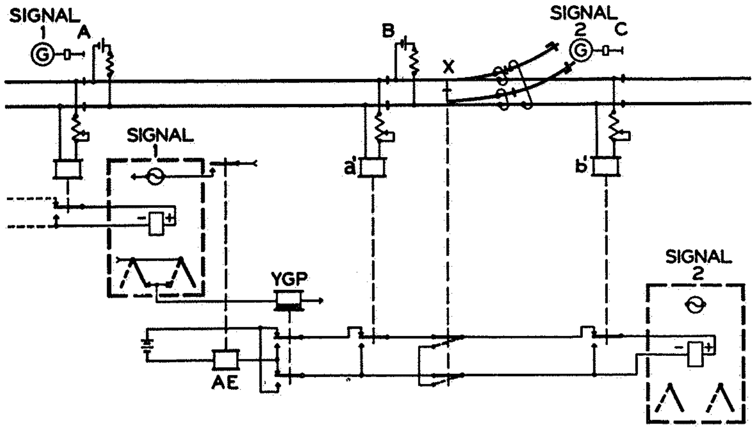

Figure 207. Simplified circuit for 2-block, 3-aspect signaling with polarized line circuit.

Third, if signal 1 is yellow or green, relay YGP is energized, and signal 2 will display a green aspect.

The YGP relay is a slow-acting relay in order to prevent the control circuit for signal 2 from opening momentarily while signal 1 changes from yellow to green or vice versa. If this were permitted, signal 2 would flash from green to yellow and back to green.

To conserve electrical energy, especially if primary cells are used, it is desirable to have the signals dark, and to light them only on the approach of a train. One scheme to accomplish this is to control the light circuit through a back contact on relay AE which is in series with the control of signal 2 and will be deenergized when a train is occupying block AC. Another scheme is to reverse the relay and battery on track circuit AB and control the light circuit through a back contact on the track relay.

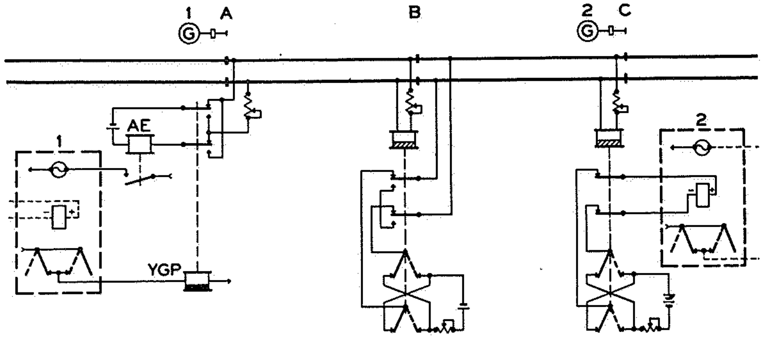

Figure 208. Simplified circuit for 2-block, 3-aspect signaling with polarized track circuits.

Polarized Track Circuit Control

Figure 208 shows a scheme commonly referred to as polarized track.

The three aspects are obtained as follows: red—by the track relay deenergized; yellow—by the track relay energized by one polarity; and green—by the track relay energized by the other polarity.

Because polarized track relays must be operated on relatively short track circuits, usually not exceeding 3000 feet, the track energy is relayed in order to convey the necessary information from one signal to the next.

Energy is fed to the track through a signal repeating relay YGP, which is deenergized when the signal is red and energized when the signal is yellow or green. This relay pole changes the track energy so that when signal 1 is red and the YGP relay is down, the polarity on the track will cause signal 2 to display yellow, and with YGP up signal 2 will show green.

With this arrangement, it is always necessary to feed energy to the track in the approach to a signal. For approach lighting a series relay (AE) is inserted in the track feed. This relay is so designed that the normal flow of current that is required to operate the track relay is insufficient to cause AE to close its front contacts. However, when a train enters the track circuit and shunts out the track relay, the current flow is increased, and AE closes its front contacts and lights the signal.

In the early application of this circuit, an ordinary polar-neutral relay was used and a slow-acting repeater of the neutral contacts was required in order to avoid an undesirable long red flash of the signal during the pole-change time, the interval between the displaying of a yellow aspect and a green aspect. This relay has been eliminated by the development of an RNP retained-neutral polar relay. The neutral contact of this relay stays closed during the pole-change interval.

AUTOMATIC BLOCK SIGNALING

DOUBLE-DIRECTION RUNNING

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Overlaps 300
Train Operation on Single Track 301
Typical Circuit 302

AUTOMATIC BLOCK SIGNALING DOUBLE-DIRECTION RUNNING

In the preceding section, we have seen a combination of signal equipment which was assembled into a workable block system for multiple track, single-direction operation, using line-controlled SA signals. Now, we have to get two such schemes combined on a common track for either-direction operation.

OVERLAPS

So far, we have assumed signals to be spaced braking distance apart. We have had no reason to include any track contacts in a signal control other than those located between the signal in question and the next signal in advance. If it suits our purpose, however, we can include as many additional track contacts as we wish. These additional track contacts constitute what is known as an *overlap*. This is the first new element encountered, and we shall expand this element as we go along.

In our illustrations, we shall show *solid* that part of a signal control which is affected by track circuits and *dotted* that portion of the signal control which has to do the advance warning. Figure 301 shows the control of signal 1 overlapped beyond signal 3—in fact, beyond signal 4—whereas signal 4 is overlapped beyond signal 2 but not beyond 1. If we consider only

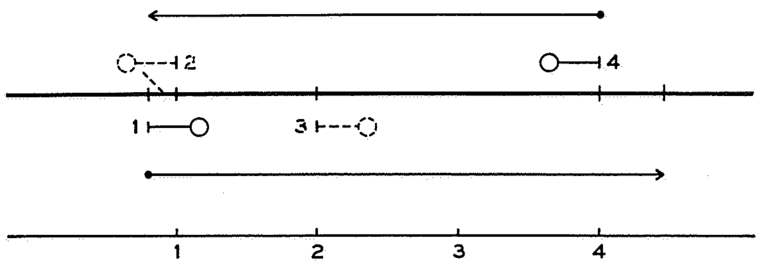

Figure 301. Diagram showing the overlap principle.

the portion of track between 1 and 4, a train in this territory is protected by these two signals, red.

Let us consider how a train would get between 1 and 4. Since it is perfectly safe to run one train without signals, let us assume that two trains are approaching signals 1 and 4 respectively. If 1 control were not extended beyond 4, both trains would proceed into this territory, each expecting to go at least to the other end of this vital spot, with disastrous results. Since there *is* an overlap, 4 will be accepted by the westbound train, with signal 1 protecting its head end. To avoid difficulty west of signal 1, we shall very conveniently install a switch and permit the westbound train to stop at 2 and then proceed at restricted speed over the switch reversed, the eastbound train meanwhile keeping clear of the switch.

Although we may not cut signal 1 control back to 4, we could if it suited our purpose, extend 4 control beyond 1, as shown in Figure 302. To occupy the vital area between signals 5 and 8, two trains approaching these signals would put them red, and both trains would have to stop, call the dispatcher to get permission to proceed, proceed by flagging ahead, or proceed at restricted speed—depending on the type of signal and its place in the rule book. If we have a siding at this point, the superior train would hold the main and the inferior train would take the siding. If there were no siding, the trains would advance towards each other, determine which was the inferior, and arrange to back that train to the nearest siding.

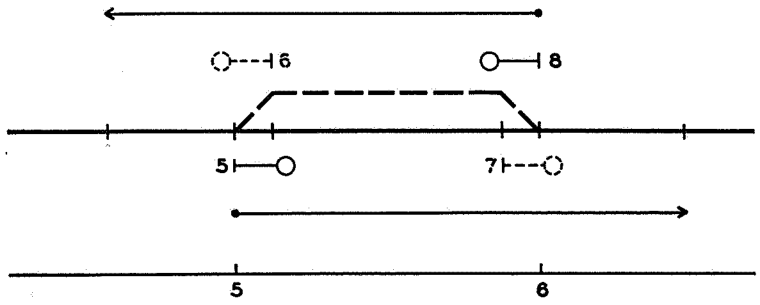

Figure 302. Overlap signal controls at a siding.

TRAIN OPERATION ON SINGLE TRACK

Figure 303 shows, diagrammatically, an arrangement of signals and signal control limits for an absolute permissive block signal system. This system, commonly called **APB**, provides full-block protection against opposing moves and allows permissive following moves. For purposes of simplifying our example, we shall assume that there is more than twice braking distance between signals 3 and 4 and between signals 9 and 14.

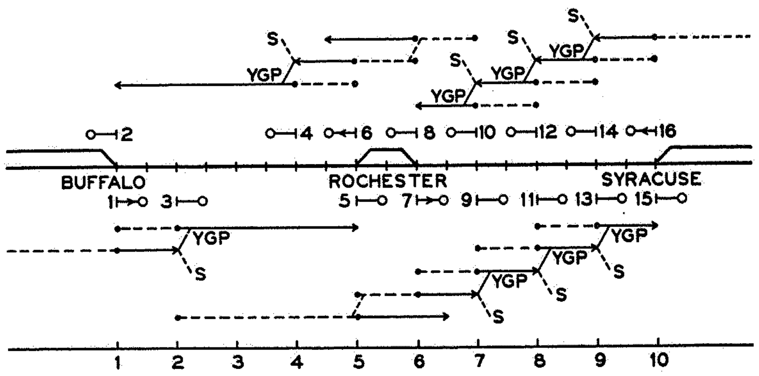

Figure 303. Diagram of absolute permissive block signal system, showing signal location and controls. Horizontal scale indicates miles.

Let us suppose that we have two trains, one at Rochester and one at Syracuse. The predetermined order of their using the track between those points, established by time table or train order, has been overlooked somewhere along the line. They start towards each other, and they arrive at signals 9 and 14 red, with braking distance for both between them. They must have left their respective stations within a matter of seconds of each other. The chances of doing this are very remote, but it could possibly happen, hence our signaling system must protect against it.

If either train had entered the single track a little ahead of the other, opposing protection would have operated and caused the opposing *absolute* signal 7 or 16 to go to stop. An absolute stop signal can be passed only on permission from the dispatcher, who may be called on the telephone usually located near the signal. In case of a failure of communications, the stop signal may be passed by flagging ahead of a train.

So far we have used signals 7, 9, 14, and 16. Signals 10, 11, 12, and 13 are simply to expedite following moves. Signals 1, 3, 4, and 6 illustrate a minimum of signaling in a similar 4-mile stretch between Buffalo and Rochester. Signals 4 and 3 are permissive signals and may be passed at restricted speed after a stop has been made—no permission or flagging ahead is required. The minimum signaling is sufficient for light traffic, with following trains an hour or more apart. An occasional train will lag, holding its following train at 4 miles for green signals, but no great harm is done. If fleet movements are to be encountered, then we must treat our railroad as shown in Figure 303 between Rochester and Syracuse.

Let us now examine Rochester siding for possibilities permitting a safe meet. The solid lines in Figures 302 and 303 are the same, and the meet is made under the protection of stop-and-proceed signals 5 and 8. But again we should see how the system works as we approach the siding from 3 and 10. If each red signal sent back a single yellow for approach warning, 6 and 7 would be red, 5 and 8 would be yellow, and 3 and 10 green. With such a system, trains accepting signals 3 and 10 green would find 5 and 8 red and would be in no position to do anything but overrun the signals. We, therefore, extend our approach warning system (Figure 303) and say that 3 and 10 shall be yellow, as well as 5 and 8, when 6 and 7 are red. Here we have another new element—*double approach,* or as it is sometimes known, green overlap.

We should mention two special conditions to be met in the application of APB. First, a feature previously considered essential was the use of a stick relay at each absolute signal to cut off the overlap and reduce the double approach to single approach for following trains. It turns out that when traffic gets heavy enough for this feature to be valuable, it is about time for cTc. Second, a problem that is present on every application is lengths of single track with insufficient braking distance between sidings to afford the protection we have shown for simultaneous entry. This is solved by the use of double or even triple approaches.

TYPICAL CIRCUIT

Referring to Figure 304, our circuits follow the pattern of single-direction block signaling, with the elements of *protection for opposing moves, overlap, directional stick circuit,* and *double approach* added.

Protection for opposing moves is shown in the control for signal 1. As soon as a westbound train passes signal 6, 6T drops, putting signal 3 to stop. When signal 3 goes to stop, contacts in the signal open the circuit to relay 3YGP. When 3YGP opens its front contacts, the circuit to signal 1 is opened, and signal 1 goes to stop.

You will note that signal 6 is controlled in a similar manner, beginning with 1T. Thus if, through some misunderstanding of train orders, an eastbound train left Buffalo at the precise instant that a westbound train left Rochester, signals 3 and 4 would go to stop as soon as relays 6T and 1T respectively opened their front contacts. Thus each train would come upon

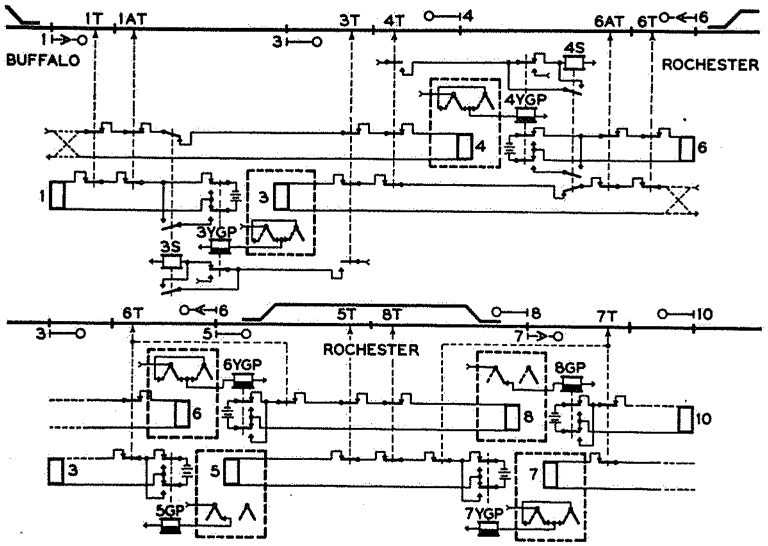

Figure 304. Simplified circuit showing elements of absolute permissive block system controls.

a red signal and would have sufficient braking distance to come to a stop before colliding with the opposing train.

Overlap is illustrated by having a front contact of track relay 6T in the control of signal 8. In a like manner 7T is included in the control of signal 5.

The *directional stick* circuit is one of many, but all accomplish the same purpose. As a train passes signal 4 clear, 4 track drops before slow-release signal repeater 4YGP drops. This allows time to pick up 4S relay, which is then held through its own contact, the back of the track, and the back of the YGP while the train is still on 4 track circuit. The stick remains up as long as the signal is red, and its repeater is down. Note that as we continue westward, 3 track does not pick up 3 stick, as 3 signal was red from the time the train passed 6 signal. Three YGP being down prevented 3 stick from picking up. The use of this relay is to apply energy of such polarity to the line as to cause the signal in the rear to display yellow for a following move. If a stick relay should remain up after its YGP is picked up, thereby removing a normal overlap for opposing moves, its back contact will open the circuit of the opposing signal.

The *double approach* is accomplished in many ways, but the use of a green signal repeater 8GP to pole change signal 10 in the rear gives the desired results as long as only one such double approach is required at any point. When the track layout indicates that successive double approaches are required, we must resort to a line wire scheme.

The picture you should bear in mind is that of a westbound train on 4T with signals 1, 3, and 4 red; and 6 yellow. The other picture is that of trains at 3 and 10 approaching Rochester with 6 and 7 red; and 3, 5, 8, and 10 yellow.

TRACK CIRCUITS
CODED

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SIGNAL CONTROL FOR ONE DIRECTION ONLY

INTRODUCTION

The coded track circuit is not essentially different from the steady-energy track circuit. It is not so much a new kind of track circuit as it is an improvement upon the steady-energy type, since it retains all the advantages and has, in addition, other desirable attributes. Among these additional advantages are: improved shunting sensitivity, improved broken-rail detection, increased average track-circuit length, improved protection against the effects of foreign currents or failure of insulated joints, and elimination of cut sections. As will be explained later, "inverse" and "follow-up" codes to effect approach locking, approach lighting, annunciation, etc., may also be applied without adding more line wires.

Because of the improved shunting sensitivity of the coded track circuit and the high efficiency of the code-responsive track relay, it is possible to increase the length of a coded track circuit well beyond the length that would operate satisfactorily with a steady energy track circuit—assuming similar conditions for each. This often permits the elimination of relayed cuts required in steady-energy track circuits.

The same factors that contribute to improved shunting sensitivity also contribute to improved broken-rail detection. The shunting sensitivity of the coded track circuit is affected directly by the relay's pickup value rather than by its release value. Furthermore, the code-responsive track relay requires more current (intermittently) than the steady-energy track relay. Therefore, the leakage resistance around a broken rail does not have to be as high to effect a stop indication with a coded track circuit as it would with a steady-energy track circuit.

Steady foreign current of sufficient strength to affect a code-responsive track relay would only tend to hold it inoperative, either picked up or released, depending on the polarity of the foreign current, and would thus insure that a stop aspect be displayed.

By interrupting or "coding" the current to the rails at different rates in accordance with the condition of the next track circuit in advance and by providing appropriate apparatus at the relay end of the track circuit that will respond selectively to the code being received, multiple proceed aspects may be controlled through the rails, thus eliminating signal-control line wires. This and other capabilities of the coded track circuit will be explained more fully in the following pages.

ELEMENTARY PRINCIPLES

Figure 401 illustrates an elementary coded track circuit. Code transmitter **CT** at the battery end of the circuit interrupts the energy to the rails 75 times per minute so that the energy in the rails pulses in alternate "on" and "off" periods.

At the other end of the track circuit, code-responsive track relay **TR** alternately picks up and releases in response to these impulses of energy and controls the flow of local energy to the master decoding transformer. The signal circuits are controlled by **HR**, a steady-energy repeater of the code-responsive track relay. **HR** is so controlled through the contacts of **TR** and by the master transformer that it will release unless **TR** is coding.

When a train enters such a track circuit, the value of the train shunt need only be sufficient to reduce the energy in the coils of **TR** relay to a point below its pickup value to cause track-detector relay **HR** to drop.

In the steady-energy d-c. track circuit, the value of the train shunt must be sufficient to reduce the energy in the track relay to a point below its release value. Inasmuch as it takes less energy to hold a relay in its picked-up position than it does to

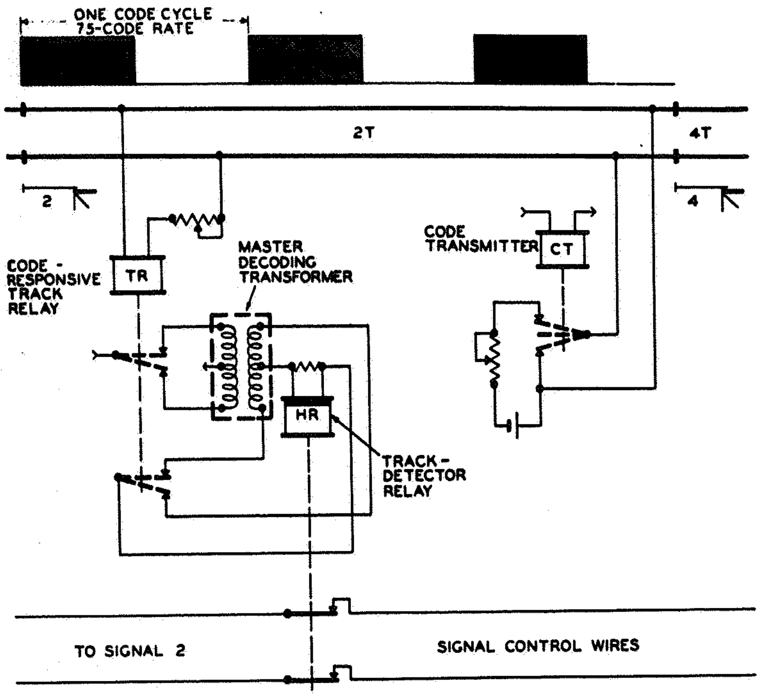


Figure 401. Simplified operational diagram of coded track circuit using one code rate and line wires.

cause a relay to pick up from its released position, the coded track circuit has a correspondingly higher shunting sensitivity. Furthermore, if for any reason the code-responsive track relay should remain in either the energized or the deenergized position, HR would drop.

APPARATUS

Code Transmitter

The code transmitter (CT) is located at the battery end of a coded track circuit. It performs the important function of controlling the current supplied to the rails so that the rails will be intermittently energized, with the "on" and "off" periods of practically uniform length. The rate at which these periods occur determines the "code" as 75, 120, 180, etc., per minute.

The code transmitter usually used is the d-c. oscillating type; a plug-in model is shown in Figure 402. It may be used with a repeater relay, depending upon the requirements of the circuit.

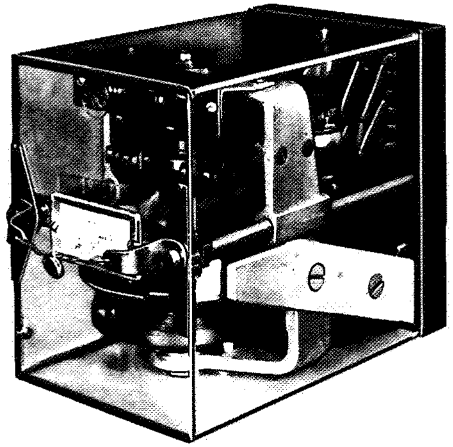


Figure 402. Plug-in type d-c. oscillating code transmitter.

Referring to the simplified operational diagram of the oscillating code transmitter, Figure 403, when energy is first applied to the coil, magnetism builds up in the pole pieces and causes the armature to rotate counterclockwise. At a given point in this counterclockwise swing, the upper cam allows its contact to open thus interrupting current to the coil and removing the magnetism. The armature, however, continues to move counterclockwise until its momentum is overcome by the increasing resistance of the spring.

The mechanical energy stored in the spring by the counterclockwise movement now moves the armature clockwise, im-

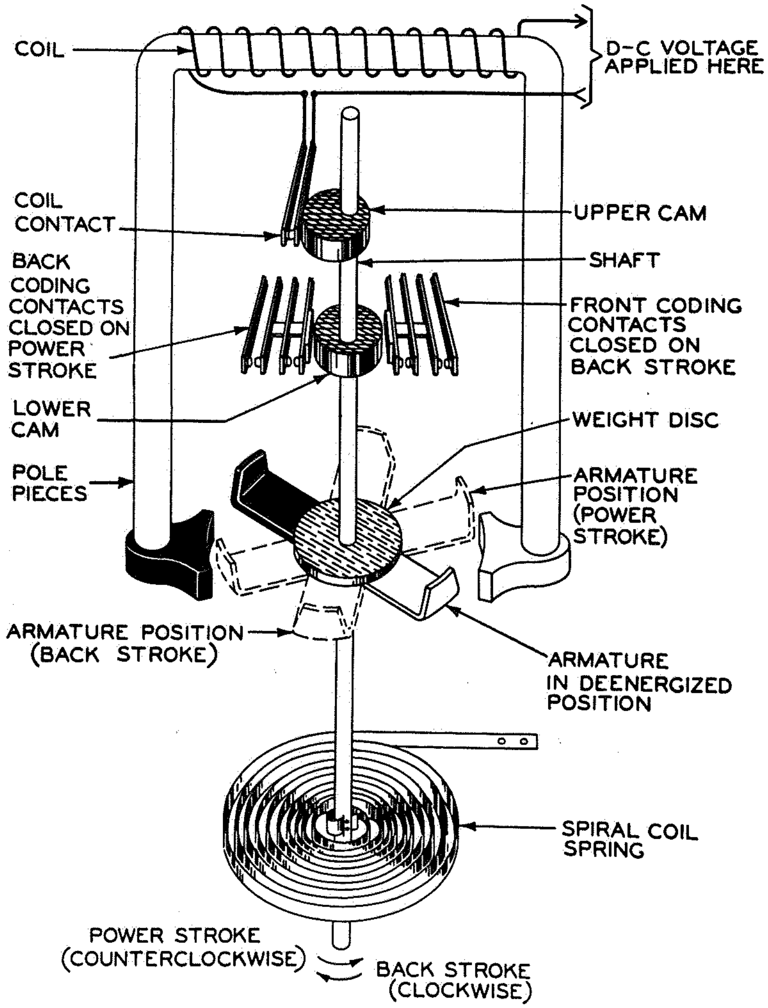

COIL
D-C VOLTAGE APPLIED HERE
COIL CONTACT
UPPER CAM
SHAFT
BACK CODING CONTACTS CLOSED ON POWER STROKE
FRONT CODING CONTACTS CLOSED ON BACK STROKE
LOWER CAM
WEIGHT DISC
POLE PIECES
ARMATURE POSITION (POWER STROKE)
ARMATURE POSITION (BACK STROKE)
ARMATURE IN DEENERGIZED POSITION
SPIRAL COIL SPRING
POWER STROKE (COUNTERCLOCKWISE)
BACK STROKE (CLOCKWISE)

Figure 403. Simplified operational diagram of oscillating code transmitter.

parting sufficient momentum to the armature to carry it past the dead-center point from which it started. As the armature passes the dead-center point, the upper cam again acts to close the coil circuit. The armature continues to rotate clockwise until the magnetic attraction and the spring overcome its momentum and start it back again—and so the oscillations continue. The recurrent pulses of magnetic attraction supply the energy to start the oscillations and to do the work of closing the contacts and overcoming the slight friction of the mechanism.

The action of the coiled spring and rotating mass may be mentally compared to the action of the balance wheel and hair spring in a watch. They constitute a rotary pendulum with a "rate" which is established by the physical properties of the spring and the rotating mass. Thus a given weight with a given spring will develop and maintain a certain frequency of oscillation. The rotating mass of the 75-code transmitter, for example, has more non-magnetic weight discs attached to it than that of the 180-code transmitter. Because of this inherent frequency characteristic of each transmitter, the code frequency is held within very close limits, regardless of normal voltage variations. The oscillating code transmitter is ruggedly designed to give years of continuous service with a minimum of attention.

Code-Responsive Track Relay

At the relay end of the track circuit, a relay is provided that will respond quickly so that it will follow the coded pulses of current supplied to the rails by the coding apparatus at the highest code rate that may be used in the system. This relay has two dependent front-back contacts.

The simplified operational diagrams, Figures 405 and 406, illustrate the theory of operation of the code-responsive track relay. The middle leg of the core is a permanent magnet. In

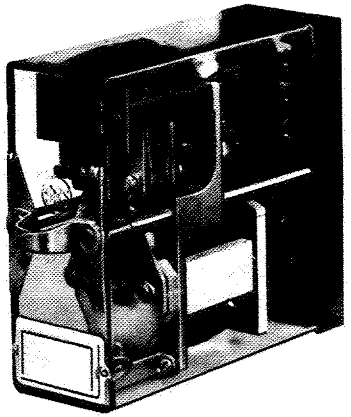


Figure 404. Code responsive track relay.

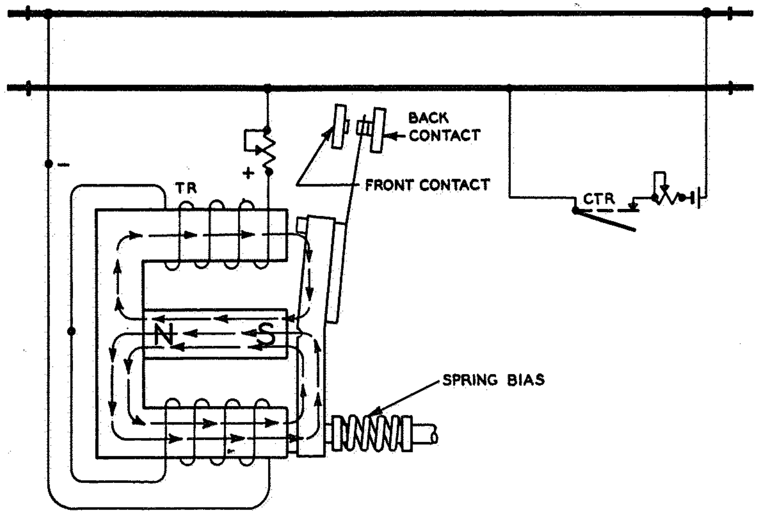


Figure 405. Simplified operational diagram of code-responsive track relay. Relay shown in position it assumes when track circuit is deenergized.

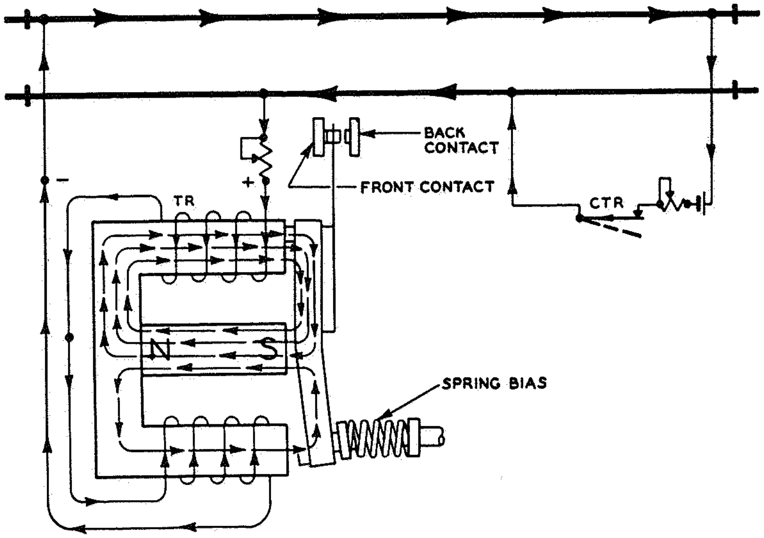


Figure 406. Simplified operational diagram of code-responsive track relay. Relay shown in position it assumes when track circuit is energized.

the deenergized position, Figure 405, a magnetic circuit is completed through the lower leg of the core and one half of the armature. Very little of the magnetism of the permanent magnets is diverted through the other leg of the core and the other half of the armature because of the greater reluctance (magnetic resistance) of the wider air gap there.

When current of the proper polarity flows through the windings, Figure 406, the current flowing in the upper coil produces magnetism that combines with that of the permanent magnet, while the current flowing through the lower coil produces magnetism opposing that of the permanent magnet. As a result, the intensity of the magnetic flux across the lower air gap decreases, but the magnetic flux across the upper air gap increases to such an intensity that the armature is attracted to it, and the front contacts are closed.

When current ceases to flow in the coils, the bias spring returns the armature to the deenergized position, Figure 405, and the back contacts are held closed by the spring and by magnetic attraction of the permanent magnet.

Thus it may be seen that the code-responsive track relay is in effect a polar biased relay, that is, it will close its front contacts only when current of the correct polarity is flowing through its coils. When the relay is deenergized or when current of wrong polarity flows through the coils, the back contacts will be held closed.

Master Decoding Transformer

The master transformer, Figure 407, (see also Figure 401) performs three functions:

1. It provides a link between the track relay and the track-detector relay, and it acts in such a manner as to provide energy to pick up the track-detector relay only when the track relay is coding.

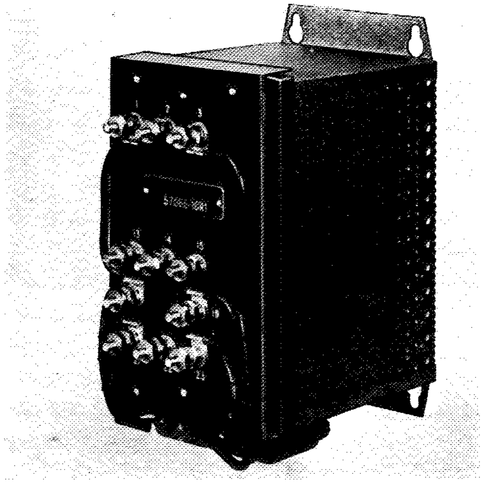


Figure 407. Master transformer.

2. It supplies an a-c. output which is mechanically rectified to furnish pulsating direct current to track-detector relay **HR**.
3. It supplies alternating current to the decoding units (described later) at the code frequency being received.

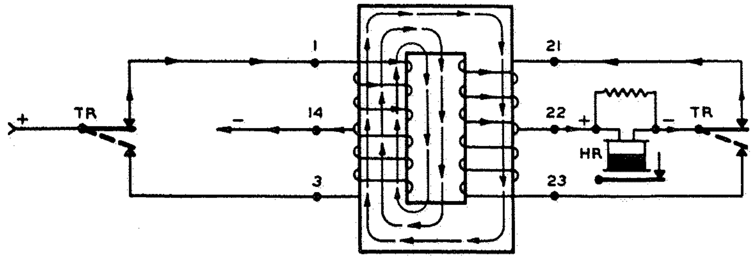
Figure 408a, an operational diagram of the master transformer, shows the condition that exists when the code-responsive track relay first makes its front contacts. As current increases in the upper half of the primary winding, the resultant rise of magnetic flux induces a voltage in the secondary windings.

Only the upper half of the secondary winding energizes track-detector relay **HR**, the current passing through the heel and front of the track relay contact at the right.

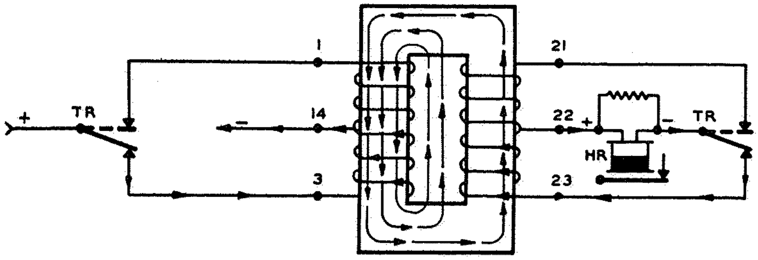
Figure 408b shows the condition that exists when the track relay first makes its back contacts. The voltage induced in the windings is now in the opposite direction because voltage is impressed on the lower half of the primary winding and the core flux is reversed.

HR is again energized by current of the same polarity, however, because the heel and back contact of the track relay now complete a circuit through **HR** and the lower half of the secondary winding.

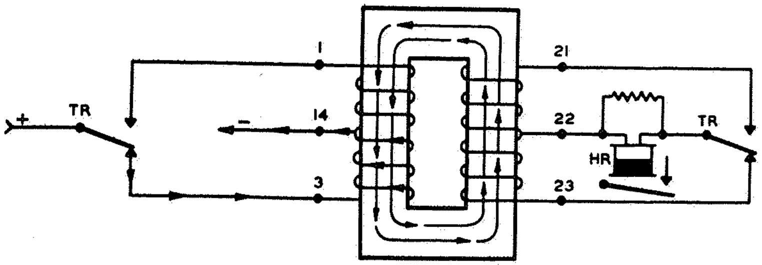
When the pulsating rail current is shunted out by the presence of a train in the block, the track relay will cease to operate, leaving its back contacts made. Thus, as shown in Figure 408c, a steady current would flow through the lower half of the primary winding; the magnetic flux would be of constant value, and no voltage would be induced in the secondary windings. The decoding unit, as will be shown later, is connected to the master transformer in series with a condenser. It is a tuned device, responding only to code impulses of the code



a. Track circuit momentarily energized.



b. Track circuit momentarily deenergized.



c. Track circuit shunted by train.

Figure 408. Simplified operational diagrams of master transformer.

rate for which it is designed.

Likewise if the track relay is steadily energized by foreign current in the track circuit, for example, its front contacts remain closed and the same condition will result—HR and the decoding units will receive no energy.

Decoding Unit

All the apparatus necessary for the development of the circuit shown in Figure 401 has thus far been described. However, line wires are still required if more than one proceed aspect is desired. We will now discuss the additional apparatus that makes possible the control of multiple proceed aspects without using any signal line wires.

To secure multiple proceed indications without the use of line wires, different codes, such as 75, 120, or 180 per minute, are applied to the rails at the battery end, the code selection

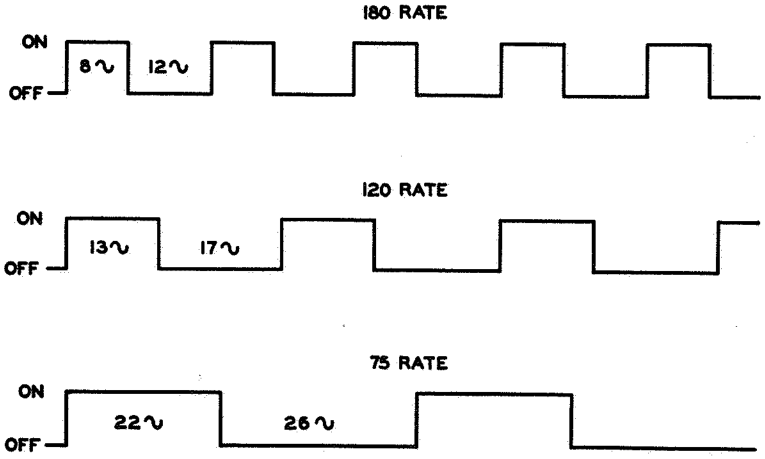


Figure 409. Code rates—"on" periods per minute.

being governed by the position of the next signal in advance; see Figure 409.

As has already been shown, the master transformer supplies an a-c. output whose frequency corresponds with that of the code being transmitted. A decoding unit, Figure 410, connected to the master transformer provides a means of identifying the code being transmitted, as the fundamental characteristic of a decoding unit is that it will pass energy to pick up the relay connected to it when the input energy is supplied at the frequency for which the decoding unit was designed and tuned, such as 120 or 180 cycles per minute.

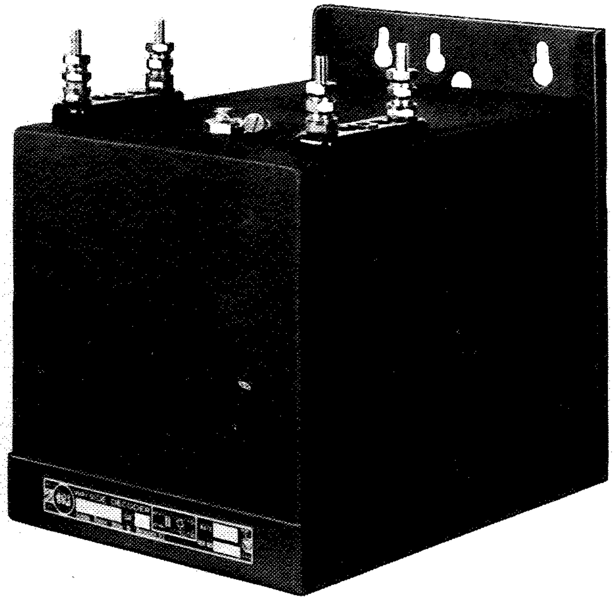


Figure 410. Decoding unit.

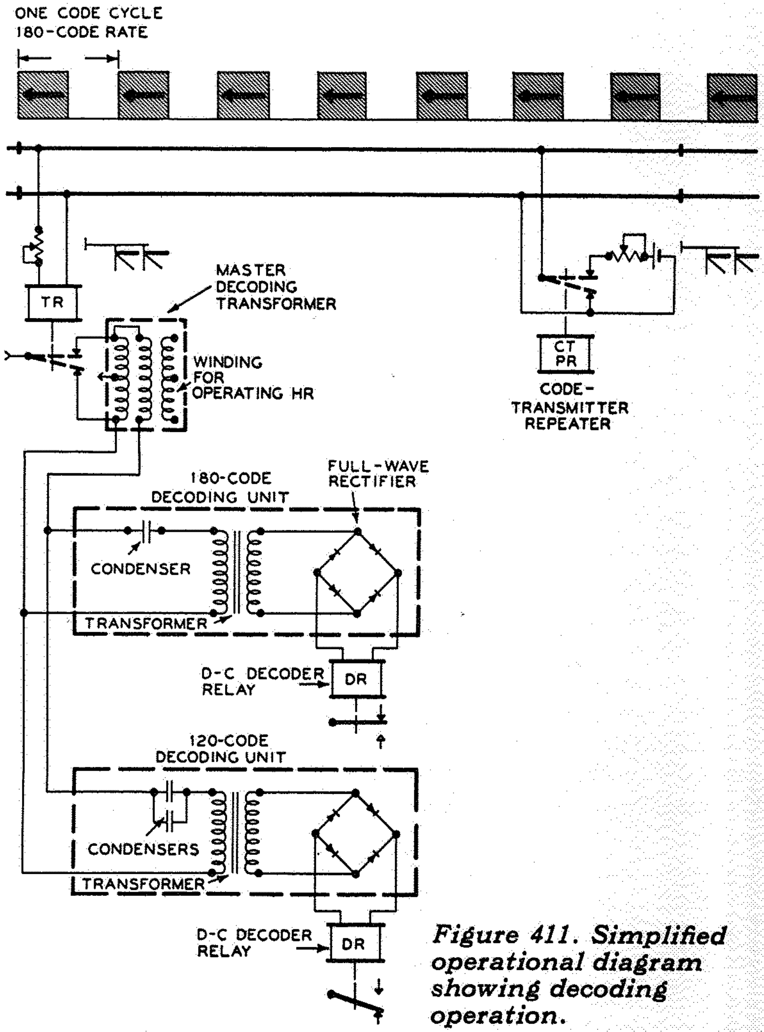

ONE CODE CYCLE
180-CODE RATE
TR
MASTER
DECODING
TRANSFORMER
WINDING
FOR
OPERATING HR
CT
PR
CODE-
TRANSMITTER
REPEATER
180-CODE
DECODING UNIT
FULL-WAVE
RECTIFIER
CONDENSER
TRANSFORMER
D-C DECODER
RELAY
DR
120-CODE
DECODING UNIT
CONDENSERS
TRANSFORMER
D-C DECODER
RELAY
DR

Figure 411. Simplified operational diagram showing decoding operation.

As shown in the simplified operational diagram, Figure 411, the decoding unit contains a transformer, a condenser, and a full-wave copper-oxide rectifier. The condenser is connected in series between the secondary of the master transformer and the primary of the reactive transformer in the decoder. The rectifier is connected across the secondary coil of the decoder transformer to convert the a-c. output to direct current to operate a d-c. relay.

In order to understand why the 180-code decoder, for example, will pick up its associated relay when it is supplied by the master transformer with 180-cycle-per-minute alternating current and yet will not pick up its relay in response to 75- or 120-cycle-per-minute alternating current, it is necessary to consider briefly the fundamentals of series resonance.

The circuit within a decoding unit includes a coil having an iron core (the primary of the decoding-unit transformer), which is an inductance, connected in series with a condenser or capacitor. When the master decoding transformer is operating at the specific frequency to which a given decoding unit has been adjusted, the master decoding transformer will supply to that decoding unit more current than at any other frequency.

If the frequency of the master decoding transformer output is below that for which the decoder circuit is tuned, the greatest opposition to the flow of current through the circuit is the capacity reactance of the condenser, since capacitive reactance increases as the frequency decreases. If the frequency of the master transformer output is too high, the current flow is restricted by the reactance of the coil, since inductive reactance increases as the frequency increases.

At a certain frequency between these high and low points the inductive reactance will be equal to the capacitive reactance. For the 180-code decoder, for example, this frequency is 180 cycles per minute. This is the resonant frequency of the circuit. Since the inductive reactance in the circuit produces a positive effect, and the capacitive reactance produces a negative effect, they cancel each other when they become equal in amount. This leaves the resistance of the circuit as the only opposition to the flow of current. Under this condition, the current through the decoding unit is at its maximum and of sufficient value so that the secondary output of the decoding-unit transformer will pick up its associated relay as shown by the graph in Figure 412.

Reference to the graph will show how even a small deviation

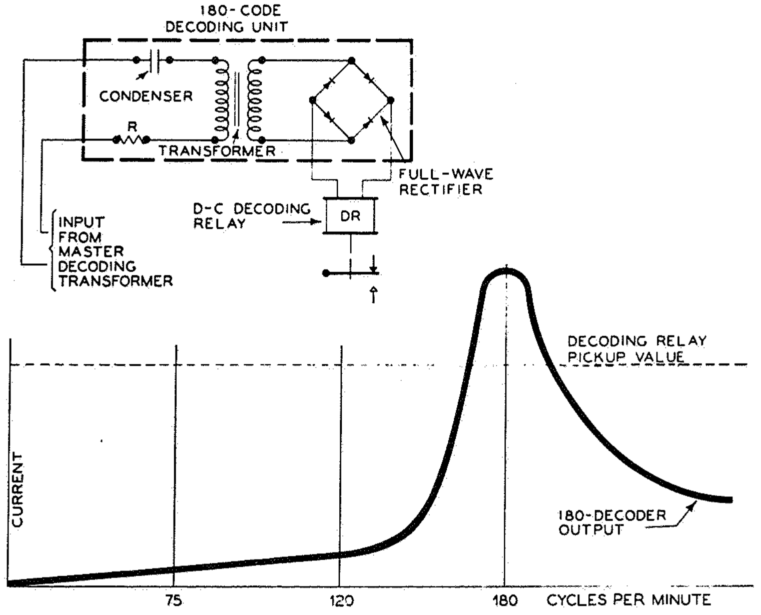


Figure 412. Circuit diagram of decoding unit and graph of decoder output current in relation to frequency of input current from master decoding transformer.

from the 180-code rate will sharply decrease the output of the decoding unit so that it does not pick up its associated relay. When the master decoding transformer output is 75 or 120 cycles per minute, for example, the capacitive reactance of the 180-code decoding unit is far too high to permit sufficient current to flow through it and produce an output that will pick up its relay.

MULTIPLE-INDICATION SIGNALING WITHOUT SIGNAL-CONTROL LINE WIRES

Sufficient apparatus has now been described to illustrate a basic circuit for two-block, multiple-indication signaling without signal-control line wires, Figure 413. Note that an additional code transmitter has been added to the circuit. There is ordinarily one more code transmitter than there are decoding units because any of the codes is detected by the operation of HR directly from the master transformer.

A code-transmitter repeater has also been added to eliminate the necessity of carrying track current through the selecting circuit.

For a Proceed Aspect

With track circuit 4T and the next track circuit in advance of 4T unoccupied, signal 4 is in the proceed position, and track-detector relay **HR** at signal 4 has its front contacts closed to feed current to the 180-code transmitter. The 180-code transmitter operates to interrupt local current to code-transmitter repeater **CTPR** at 180 impulses per minute. **CTPR**, in turn, interrupts the current fed to the rails (2T) 180 times per minute.

Code-responsive track relay **TR** at signal 2 follows the 180 rail code and codes local current to the master decoding transformer, alternately energizing the transformer primary windings and thus producing an alternating voltage which, when mechanically rectified by a second contact on **TR**, provides direct current to pick up slow-acting track-detector relay **HR**.

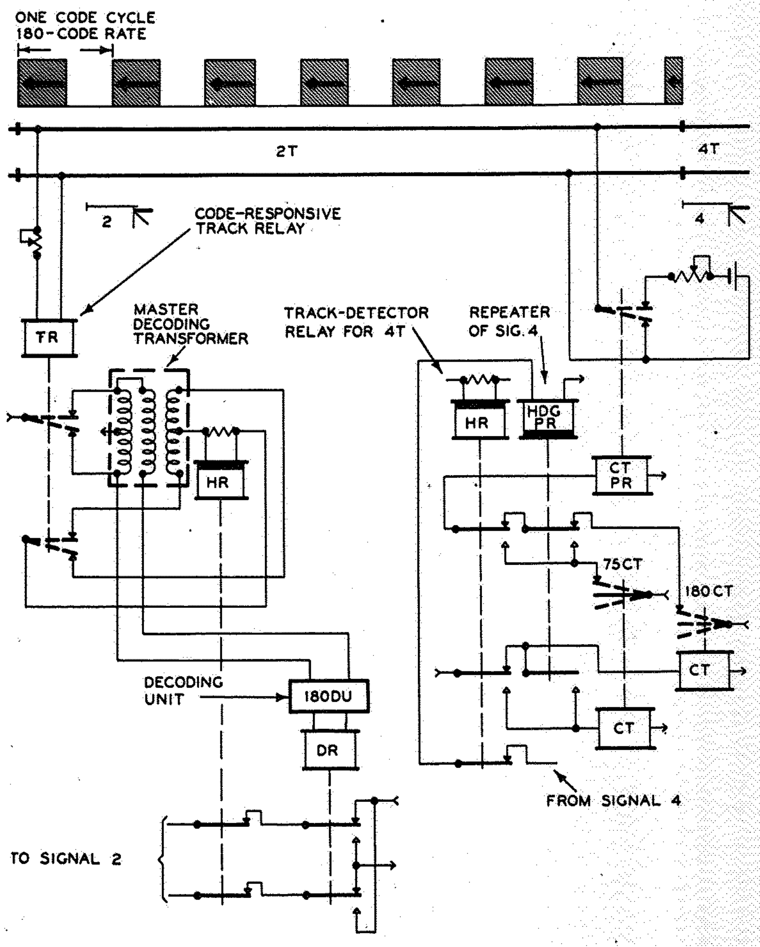


Figure 413. Simplified circuit for 2-block 3-indication coded track circuit without signal-control line wires. Contacts are shown in the positions they assume when tracks 2T and 4T are unoccupied.

The master decoding transformer also supplies alternating current at the 180 frequency to the 180-code decoding unit.

The 180-code decoding unit, which is tuned for 180 cycles per minute (3 cycles per second), passes the 180-code energy to pick up decoding relay **DR**. With **HR** and **DR** up, signal 2 displays a proceed aspect.

For a Stop Aspect

With track circuit 2T occupied and track circuit 4T and the track circuit in advance of 4T unoccupied, the 180-code transmitter continues to operate as in the preceding instance, and code-transmitter repeater **CTPR** continues to interrupt local current to the rails (2T) at 180 impulses per minute.

The coded current cannot reach code-responsive track relay **TR** to operate it because of the train shunt. With **TR** no longer following the code, pulsing current is no longer fed to the master decoding transformer, and it produces no output either to pick up track-detector relay **HR** or to pick up **DR** through the decoding unit. With both **HR** and **DR** released, signal 2 displays a stop aspect.

For an Approach Aspect

With 4T occupied and 2T unoccupied, track-detector relay **HR** and signal 4 repeater relay **HDGPR** are released and close their back contacts. This interrupts the local current to the 180-code transmitter and applies it to the 75-code transmitter. The 75-code transmitter operates to cause code-transmitter repeater **CTPR** to interrupt the current fed to the rails (2T) 75 times per minute.

Code-responsive track relay **TR** follows this 75-code and codes local current to the master decoding transformer at the same rate, thus energizing **HR**. The master decoding transformer output to the 180-code decoder is now alternating at 75 cycles per minute. The 180-code decoder will not pass current to pick up its associated relay, **DR**, when energized at other than 180 frequency. Thus **DR** will not pick up. With **DR** released and **HR** picked up, signal 2 displays an approach aspect. When the train clears track circuit 4T, **HR** and **HDGPR** will again be picked up, and the circuit will return to the condition as described under "For a Proceed Aspect."

APPROACH LIGHTING

It is common practice to light signals only when a train is approaching, in order to save energy, lamps, etc. This approach lighting may be secured in various ways with coded track circuits. One method in general use is shown in Figure 414, where the approach relay is connected in series with contacts of the **CTPR** relay. Approach lighting is effective approximately 4000 feet in advance of the train, the distance being dependent upon ballast resistance and other track conditions.

Series Circuit

Referring to Figure 414, series approach lighting operates by

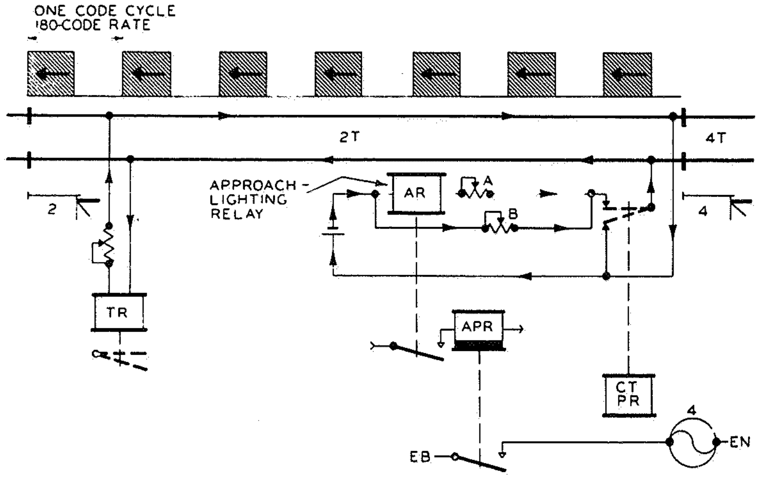


Figure 414. Simplified series approach-lighting circuit Contacts shown coding. Track 2T is unoccupied.

increasing energy to AR as the train nears. Since it is economical in current consumption, it is generally recommended for primary-battery installations.

With track circuit 2T unoccupied, current from the positive side of the track battery flows through two parallel branches: one through approach relay AR and resistor A, the other through resistor B. The branches then join, and the current flows through the coding contacts, out to the rails, and through code-responsive track relay TR. Resistors A and B are so adjusted that most of the current flows through resistor B, and the current flowing through AR and resistor A is not great enough to operate AR.

When a train enters track circuit 2T, the low resistance of the train shunt permits an increased flow of current from the track battery, and sufficient current then flows through AR and resistor A to make AR repeat the code to hold up slow-release relay APR. The lighting circuit to signal 4 is then closed through the front contact of APR. Note that AR responds to the coder only when the track circuit is occupied.

Inverse Code

The series approach-lighting circuit just described does not provide for full-block approach lighting under all conditions. This can be accomplished without the use of line wires by sending an "inverse code" from the relay end of a track circuit to the battery end. The current impulses for an inverse code are transmitted through the rails during the "off" periods of the direct code; see Figure 415.

Figure 416 illustrates the fundamentals of a typical inverse-code circuit. The contacts are shown in the positions they assume during the transmission of a direct-code current impulse. At the leaving end, code-transmitter repeater CTPR is picked up, and current flows to the rails in series with approach relay AR, which is a polar stick relay. It is magnetically held

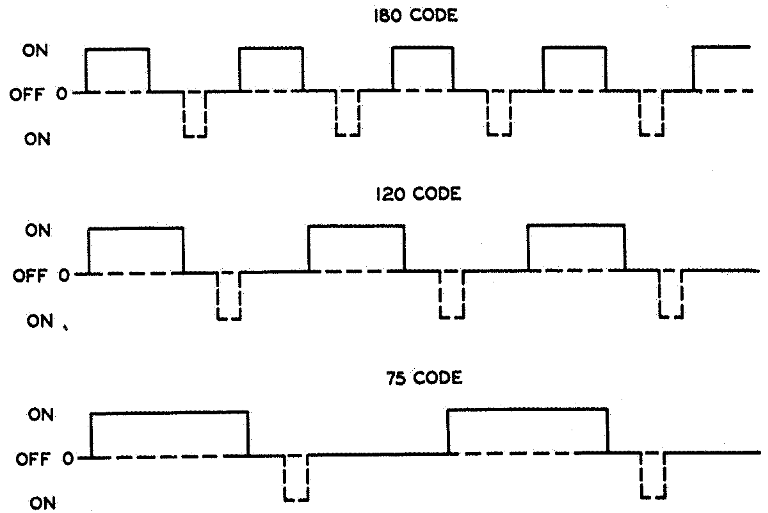


Figure 415. Code rates and inverse code.

in its last-operated position. With positive current entering its negative terminal, it assumes its reversed position.

Flowing through the rails to the entering end, the current passes through the back contact of an impulse relay, TPA, to pick up code-responsive track relay TR, which is a polar-biased relay as described previously. When TR picks up, a direct-code impulse is applied to the master transformer and to the decoding unit corresponding to the code being received. (For purposes of simplification these units are not shown. Operation would be same as has been described previously.)

Thus far the path of a direct-code impulse has been described. The following deals with the path of an inverse-code impulse as shown in Figure 417. This is the same circuit as shown in Figure 416 except that the contacts are shown in the positions they assume during the transmission of an inverse-code current impulse.

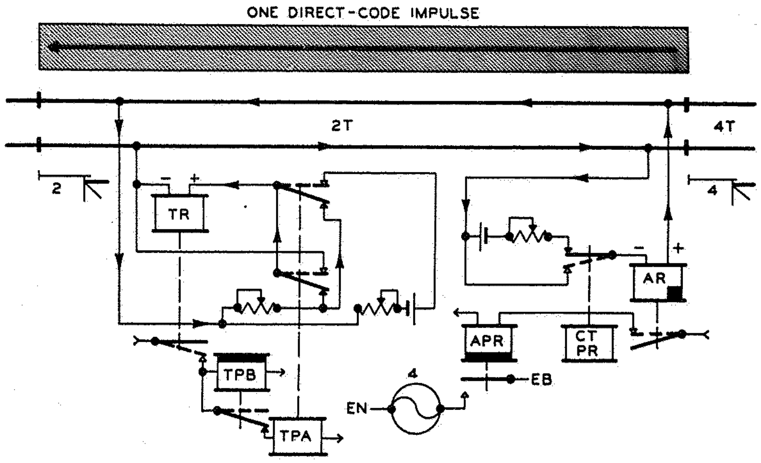


Figure 416. Simplified typical inverse-code circuit. Circuit is shown with contacts positioned at the instant of a direct-code impulse.

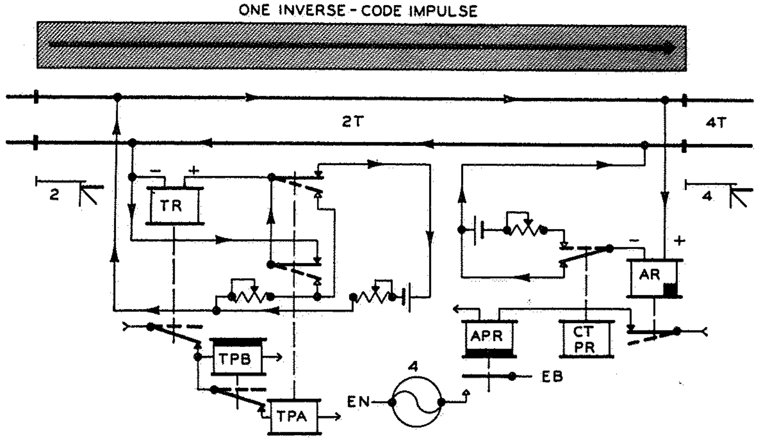


Figure 417. Simplified typical inverse-code circuit. Circuit is shown with contacts positioned at the instant of an inverse-code impulse.

To return to the leaving end, **CTPR** closes its back contacts, connecting the negative terminal of **AR** to the negative track lead. The positive terminal of **AR** is regularly connected to the positive track lead.

The current of the direct-code impulse ceases to flow through **TR**, and **TR** drops, applying local current through its back contacts to both **TPB** and impulse relay **TPA**. **TPA** picks up faster than **TPB**, which is slightly slow pickup, thus closing its contacts before **TPB** can pick up and break the circuit to it. During the interval that **TPA** is up, a short impulse of inverse-code current is applied to the rails. The duration of this inverse-code current impulse is governed by the time **TPA** remains in its energized position.

Passing through the rails to the leaving end, the inverse-code current flows through polar-stick relay **AR** at its positive terminal, and the relay assumes its normal position. Local current then passes through the front contacts of **AR** and picks up **APR**. **APR** is sufficiently slow in releasing so that the recurring current impulses received through front contacts of **AR** will hold it up.

A train entering track circuit 2T prevents **TR** from again picking up. With **TR** back contacts steadily closed, **TPB** remains up and **TPA** remains down, thus stopping transmission of the inverse-code current impulses. The direct-code current impulses now pass through the circuit completed by the train shunt, and **AR** is driven to its reversed or "dropped" position. Thus current is cut off entirely from **APR**, and it drops to close an approach-lighting circuit to signal 4. Note that this system gives full-block indication, as the inverse code ceases immediately upon entry of a train into track circuit 2T.

Decoding Inverse Code

When inverse code is used to control vital circuits such as approach locking, annunciation, indication, etc., it is generally considered preferable to decode the inverse code, using an arrangement such as is shown in Figure 418, where **APR** is controlled by current derived from a master decoding transformer. This system requires that **AR** be continuously pulsing in order to hold **APR** with its front contacts closed.

Figure 418 represents the circuit as coding, that is, responding to the recurring current impulses of direct and inverse code. The approximate relative spacing and durations of the inverse code current impulses and 180-rate direct-code current impulses are illustrated in the code pattern diagram above the circuit.

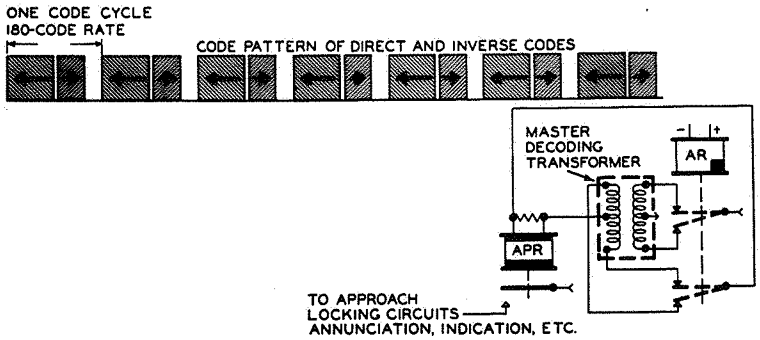


Figure 418. Portion of simplified typical inverse-code circuit showing method of decoding inverse code. Circuit is shown with contacts coding, track circuit unoccupied.

CUT SECTIONS

In installations where signals are spaced so far apart that the distances between signals are greater than the practical operating length of a coded track circuit, it obviously becomes necessary to introduce a code-repeating cut section. It should be noted here that where one cut section would be required for a coded installation, two or even more cut sections would probably be required for steady-energy track circuiting of the same installation.

For Direct Code Only

Figure 419 shows a cut section for use in installations with direct code only. The polarities of circuits **A2T** and **B2T** are as shown to insure that restrictive signals will be displayed if both insulated joints at the cut section should become defective. In such a case, the track battery at the cut will retain **TR** in the energized position, no code will be transmitted to **A2T**, and signal 2 will display its most restrictive aspect.

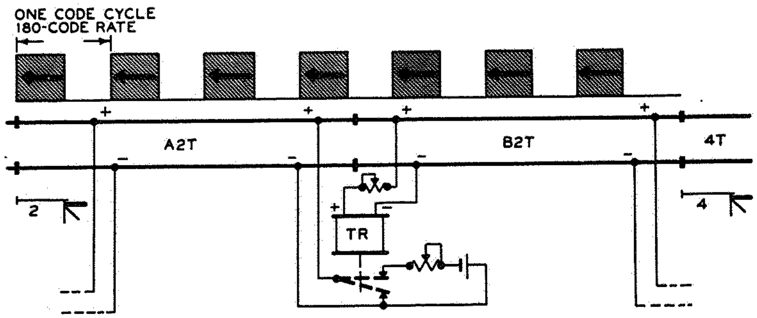


Figure 419. Simplified typical cut-section circuit for direct code only.

For Both Direct and Inverse Codes

Figure 420 shows the fundamentals of a cut section for an installation using both direct and inverse codes. Operation is as follows: when a direct-code current impulse is applied to the rails of track section **B2T** at signal 4, code-responsive track relay **TR** is picked up through back contacts of **TPA**. With **TR** up, a direct-code current impulse is relayed to **A2T** through front contacts 2 of **TR** and through the coil of **AR**. **AR** is a polar-stick relay. It is magnetically held in its last-operated position. With positive current entering its negative terminal, it is driven down and closes its back contacts, applying current to the master decoding transformer, which, in turn, energizes

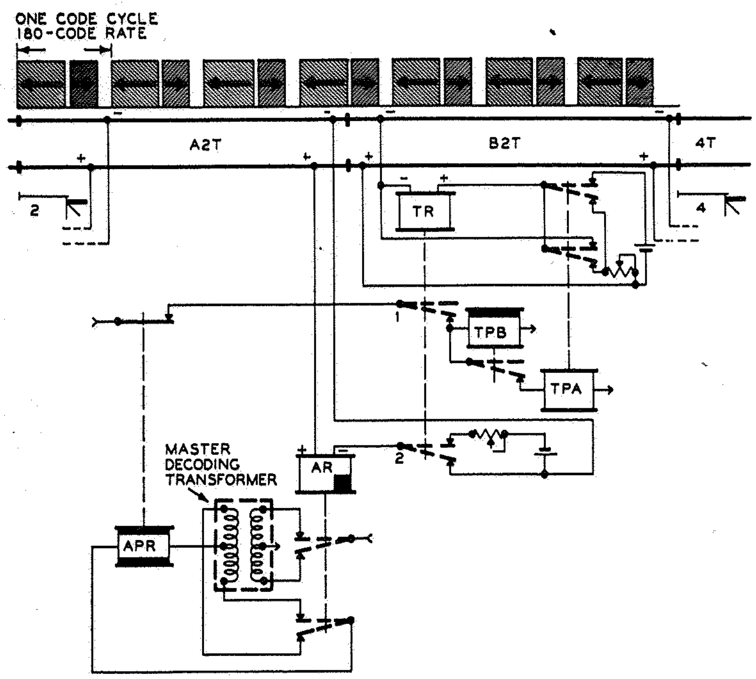

ONE CODE CYCLE
180-CODE RATE
A2T
B2T
4T
2
4
TR
TPB
TPA
1
2
MASTER
DECODING
TRANSFORMER
AR
APR

Figure 420. Simplified typical cut-section circuit for both direct and inverse codes.

APR in the manner described in the section concerning the master transformer.

When the direct-code impulse ceases and B2T is deenergized, TR drops and TPA is then energized through the front contact of APR, TR back contact 1, and the back contact of TPB. (TPB picks up less quickly than TPA.) With TPA up, an inverse-code current impulse is applied to B2T through the front contacts of TPA. The inverse-code current impulse is terminated when TPB picks up and drops TPA.

Although the inverse-code impulses transmitted to B2T are

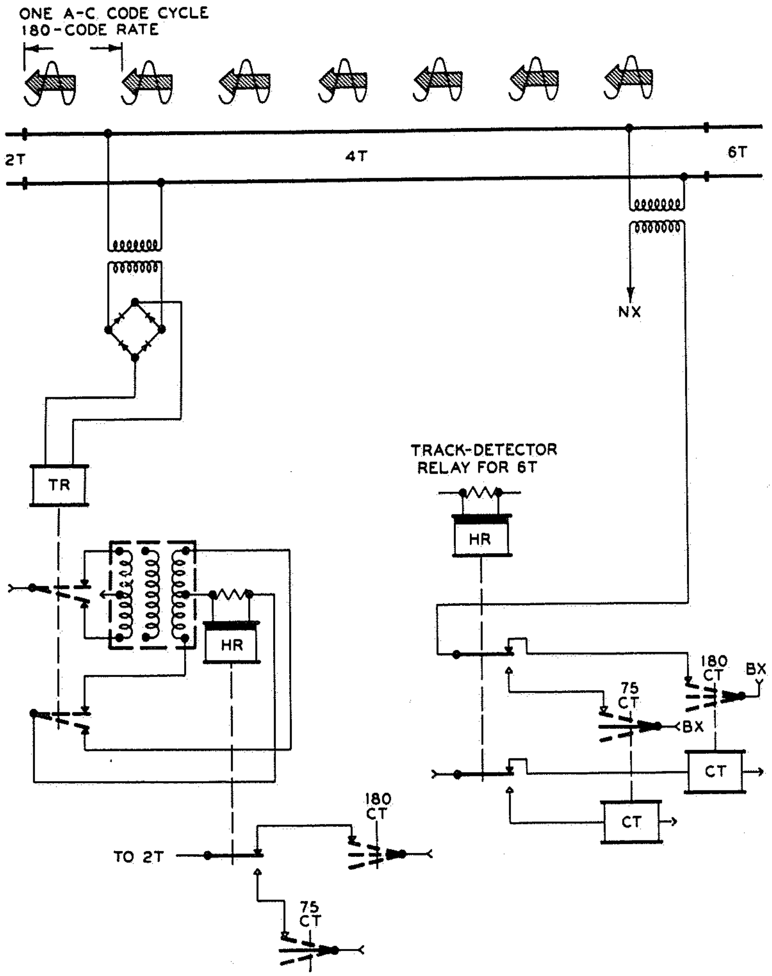

ONE A-C CODE CYCLE
180-CODE RATE
2T
4T
6T
NX
TR
TRACK-DETECTOR
RELAY FOR 6T
HR
HR
180
CT
BX
75
CT
BX
CT
CT
TO 2T
180
CT
75
CT

Figure 421. Simplified circuit for coded a-c. track circuit for cab signals without wayside signals.

originated at the cut section, they can be transmitted only when **AR** is being alternately picked up by an inverse-code impulse from A2T and driven down by the relayed direct-code impulses from B2T, since **APR** will hold its front contact closed only when **AR** is coding. Thus, whenever the inverse-code current impulses cease to flow in A2T, none will be transmitted to B2T.

CODED TRACK CIRCUIT FOR CAB SIGNALS

Figure 421 shows a simplified circuit for coded track circuits designed to operate cab signals on installations where there are no wayside signals. (For engine-borne equipment, see section on cab signals.)

This is practically the same as the elementary circuit for 2-block, 3-indication signaling shown in Figure 413, except that the codes are selected by **HR** only, and alternating instead of direct current is fed to the track circuits. (Modern G-R-S cab signaling equipment functions equally well on either a-c. or d-c. code impulses.) The alternating current coded by the code transmitter is fed to the primary of a track transformer. The pulses of alternating current produced in the secondary winding are fed to the rails and operate the engine-borne cab signaling equipment in accordance with the code frequency. 180-code causes a proceed aspect to be displayed; 75-code caution; and no code, a stop aspect.

At the relay end of the track circuit, the a-c. code impulses are rectified to operate the d-c. code-responsive track relay.

TRAKODE—SIGNAL CONTROL FOR BOTH DIRECTIONS

INTRODUCTION

Another form of coded track circuit control is known as G-R-S Trakode. This system employs track circuits in which the energy is polarized, and pulsates at a relatively slow rate. These track circuits provide a means of controlling wayside signals in both directions without the use of line wires. Hence the system may be applied to control absolute permissive block signaling or the automatic signals in centralized traffic control territory.

Trakode can also be used to control approach locking, approach indication, and electric switch locking on tracks signaled for double direction running. It may be used with all types of signals and also with intermittent inductive train control.

Due to the pulsating nature of the track energy, the track circuits can usually be considerably longer than conventional direct current track circuits. The slow rate of pulsation lengthens the service life of the code responsive relays.

OPERATION

To help understand the basic principles of Trakode, consider a polar track circuit having a polar-biased track relay. This relay is equipped with two armatures, one responding to each polarity of current. By pole changing the current at the transmitting end of the track circuit, two pieces of information can be sent to the relay end. This could be used to control an **H** or a **D** relay for controlling a signal. By slowly pulsating this current so that the track circuit is alternately energized for a fraction of a second and then deenergized for about two seconds, more can be accomplished as follows:

1. Track circuits can be made longer.
2. By changing polarity, positive and negative code char-

acters are available, but by pulsating the energy, two more characters may be transmitted. This is done by pole changing the current in the middle of an energized period, so that one rail is first negative and then positive in respect to the other. The order may be reversed so that positive is first. Hence these code characters are negative-positive and positive-negative respectively. At the receiving end of the track circuit, decoding units detect which of the four characters is received.

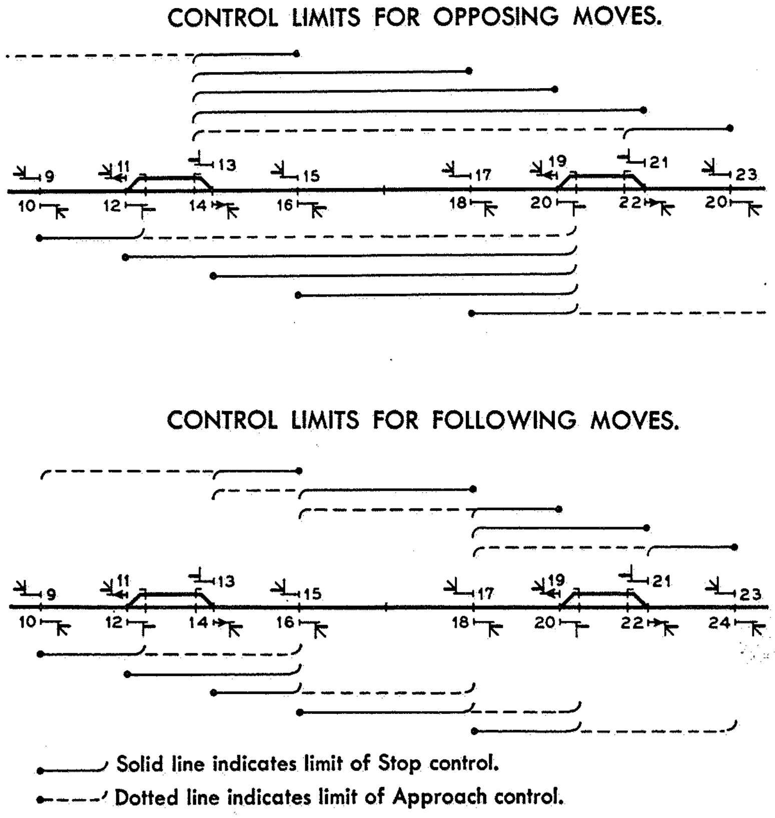
3. In the long deenergized period, the same information may be transmitted back from the relay end of the track circuit. Therefore, any one of the four characters may be used to control an opposing signal.

A pulse transmitted from a head block (end of siding) is received at the first intermediate signal, or repeating cut location, and is repeated to the next track circuit as soon as it is received. The pulse is thus repeated through a succession of track circuits until it reaches the next head block.

However, at the intermediate signals, the character of the pulse about to be repeated may be changed from that being received, to indicate the position of the intermediate signal. When this changed pulse is received at the next head block, it conditions the circuits so that a similar pulse is transmitted and repeated back to the first head block, during the deenergized period between pulses.

It must be remembered that for normal Trakode operation, only one pulse is being transmitted through a block at a time. A pulse is sent in one direction, and after it has been received at the other end, another pulse is sent back. This is termed "dependent" coding, since the transmission circuits at the end of the block are conditioned by the pulse being received so that they will transmit a pulse back as soon as reception is ended.

When a train enters a block, it prevents the transmission of pulses to the opposite end and so ends the dependent coding. It also puts all opposing signals in the block to stop. The apparatus at the opposite end of the block then transmits pulses at a fixed rate and with polarity characteristics to give the proper signal indications to the train. Such transmission is termed "independent" coding.


CONTROL LIMITS FOR OPPOSING MOVES.

CONTROL LIMITS FOR FOLLOWING MOVES.

Solid line indicates limit of Stop control.

Dotted line indicates limit of Approach control.

Figure 422. Simple APB system, showing signal controls.

When Trakode is used in APB signaling, the tumbledown time of the opposing signals is not dependent upon the cascaded times of the signal mechanisms or their slow repeaters. Since the entrance of a train will release all opposing track relays almost simultaneously, the opposing signals will go to stop at the same time, regardless of the number of intermediate signals in the block. Also, failure of any intermediate signal to clear will not affect clearing of other intermediate signals between the failed intermediate and the leaving signal.

APB SIGNAL CONTROL

Figure 422 shows a typical APB signaling layout with control limits for opposing and following moves. This particular arrangement of controls is shown here only for the purpose of demonstrating Trakode and may be simpler or more complex than shown. The opposing stop control of entering signal 21, for example, does not have to reach all the way to the opposing leaving end, as shown.

Figure 423 shows a typical track diagram with the signaling arranged for APB operation. The diagrams show successively how the signals are controlled by the polarized Trakode pulses as a train passes from station B to station C. The signal aspects are controlled by the presence or absence of coded energy in the track circuits and by the polarities of the codes as follows:

Aspects	*Code*
green	+
yellow	–
red	0

Diagram A shows the normal condition with no train present. All the signals are normally clear for both directions of traffic. All of the pulses for controlling the signals to green are shown as positive and are transmitted, in the direction of the arrows, alternately from station B to station C, and from C to B. The

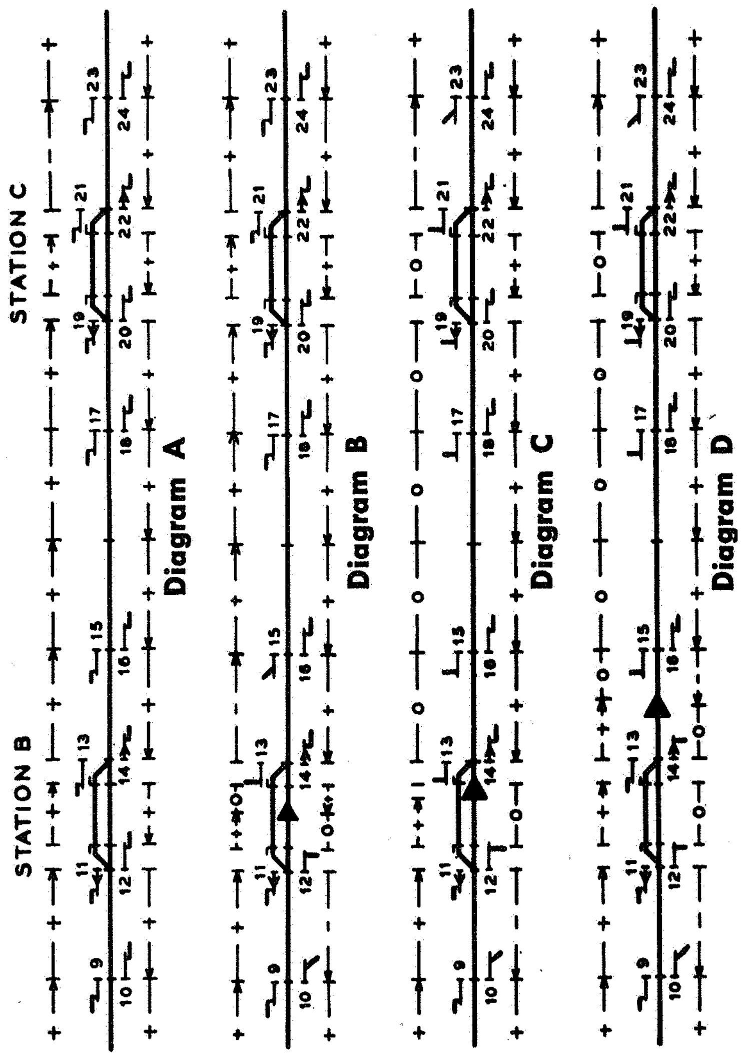


Figure 423. Trakode APB signaling (continued on next page).

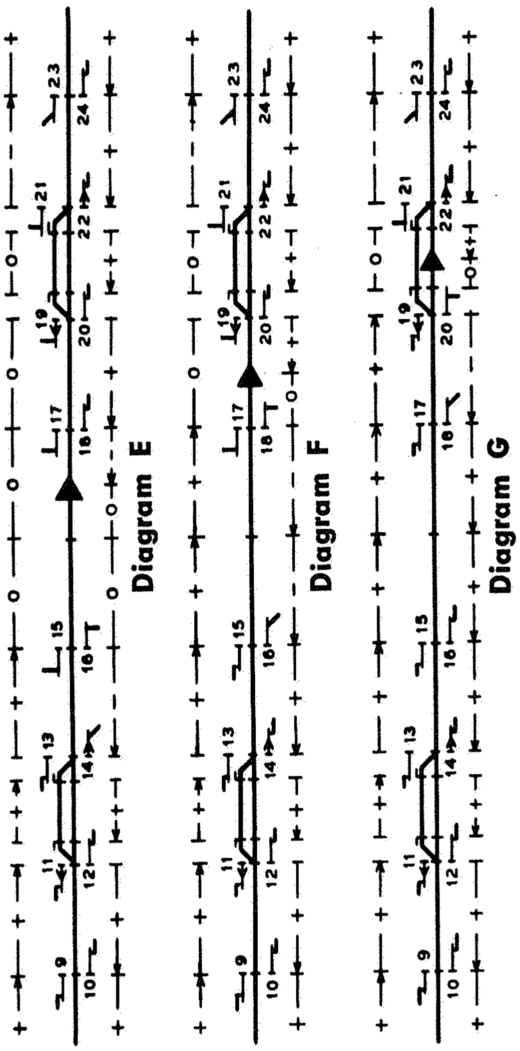


Diagram E

Diagram F

Diagram G

Figure 423. Trakode APB signaling (continued).

dependent coding with the repeating action from track circuit to track circuit is normally present in each section, except the detector track circuit at each siding end.

When B transmits a particular pulse to C and it is received, C in turn sends a pulse back to B with the same repeat operation. The polarity of the pulses need not be the same.

Diagram B shows a train at station B, with the block ahead of it clear to C. The dependent westbound coding behind the train has been removed, thus controlling signal 12 to the red aspect. This causes negative pulses to be transmitted in the next track circuit to the rear so that signal 10 is now at yellow, for following moves. Opposing signals 13 and 15 have likewise been controlled to red and yellow respectively.

In Diagram C, the train has moved onto the detector track circuit. The overlap has been arranged so that this removes all eastbound transmission right up to station C, and causes a tumbledown of westbound signals 13, 15, 17, 19, and 21 to red. Signal 21 at red causes negative pulses to be transmitted to signal 23, controlling it to yellow. Station C, after waiting the normal time for pulses to arrive from B, changes to independent coding and continues to send positive pulses toward B, keeping the eastbound signals cleared for the train to proceed toward C.

In Diagram D, the train has accepted signal 14, cutting off westbound positive pulses and placing 14 at red. Signal 12 remains at red rather than changing to a yellow aspect because the train is still in the overlap limits of signal 12 as shown in Figure 422. Note that independent positive pulses are transmitted toward the train from signal 13. The train nearing signal 16 has actuated the approach circuit which changes to negative the pulses feeding from signal 16 to the train.

In Diagram E, the train has passed signal 16, leaving it at red. Signal 16 transmits negative pulses to control signal 14 to yellow for a following move, and 14 transmits positive pulses to control signal 12 to green. Note that although positive pulses are being transmitted from signal 13 to signal 15, signal 15 does not clear because of the directional stick circuit, which also prevents transmission toward signal 17. The approach-actuated stick circuit at signal 18 changes the positive pulses feeding from signal 18 toward the train to negative pulses.

In Diagram F, the train has passed signal 18, leaving it at red. Signal 18 transmits negative pulses to control signal 16 to yellow, which in turn transmits positive pulses to control signal 14 to green. Independent positive pulses feed toward the train from signal 20.

In Diagram G, the train has moved past signal 20 which thereupon goes to red and allows the negative code in the track circuit to the rear to release the directional stick relay associated with signal 18. The repeat of the pulses through all the track circuits in the block allows dependent coding to be again established upon the reception of the first pulse at signal 19.

TYPICAL SIDING

The block diagram in Figure 424 shows the function organization of Trakode when applied to a typical siding. Each siding end has a detector track circuit which serves a two-fold purpose. It provides additional overlap against simultaneous entry and also isolates the two Trakode circuits, thereby protecting against the breakdown of insulated joints. The signaling is arranged for APB operation in both directions. Signals are three-position except those governing entrance to double track. These are two-position in this instance for reasons of simplicity, although Trakode is capable of controlling a third aspect if desired. For the same reasons, only two code characters, positive and negative, will be used in the circuit descriptions to follow although four characters are available.

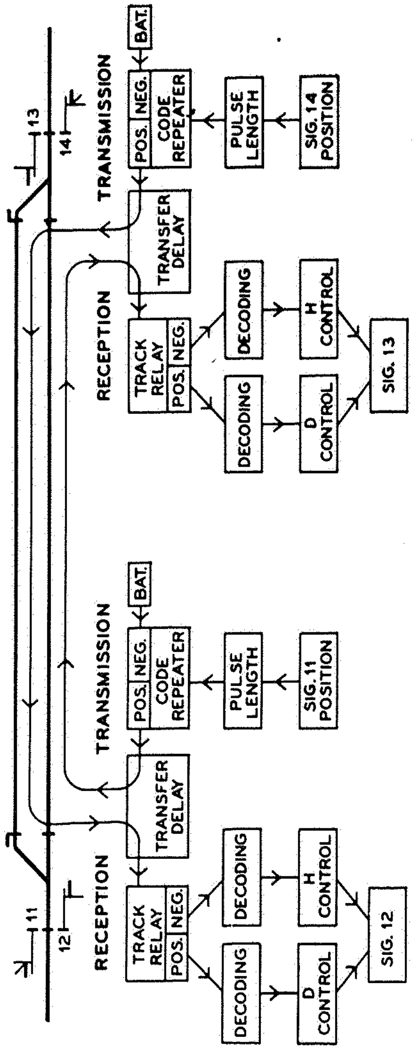

TRANSMISSION
RECEPTION
TRANSMISSION
RECEPTION
13
14
11
12
BAT.
POS. NEG.
CODE REPEATER
PULSE LENGTH
SIG. 14 POSITION
TRANSFER DELAY
TRACK RELAY
POS. NEG.
DECODING
DECODING
H CONTROL
D CONTROL
SIG. 13
BAT.
POS. NEG.
CODE REPEATER
PULSE LENGTH
SIG. 11 POSITION
TRANSFER DELAY
TRACK RELAY
POS. NEG.
DECODING
DECODING
H CONTROL
D CONTROL
SIG. 12

Figure 424. Function diagram of Trakode.

Briefly, the transmission procedure involves the following steps:

1. The polarity of the pulses to be transmitted is determined by the position of a particular signal.
2. The length of each pulse, and therefore the rate of transmission, is predetermined.
3. The pulse, positive or negative, is generated and applied to the rails from the battery.
4. A time delay is provided between transmission and reception of successive pulses. This is to prevent a possible induced voltage from the rails (rail kick) from operating the track relay inadvertently.

At the opposite end of the track circuit, reception of the pulses takes place thus:

1. The track relay responds to the polarity of each pulse by operating one of its two armatures as indicated by **POS.** and **NEG.**
2. The pulse activates a code detecting unit which operates one of the control relays.
3. Either the **H** or **D** signal control relay picks up, according to the pulse polarity, and remains up as long as pulses of the same polarity are received.
4. The **H** relay responds to negative pulses and controls the signal to the yellow aspect, and the **D** responds to positive pulses for a green aspect.

The simplified circuits in Figure 425 are for a typical siding as shown in the function diagram. It is assumed that conditions are normal, that is, the switches are lined for a move on the main track and the signals show the green aspect. Therefore, positive pulses are being dependently transmitted in both directions, and received to clear the two-position signals 12 and 13.

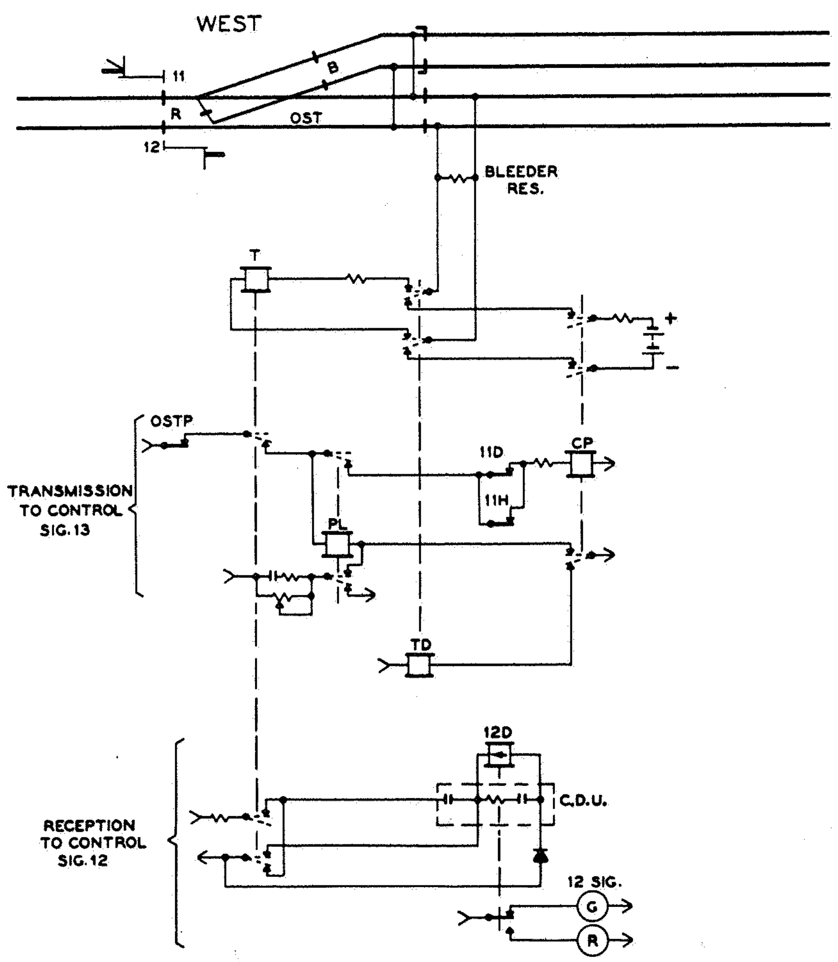
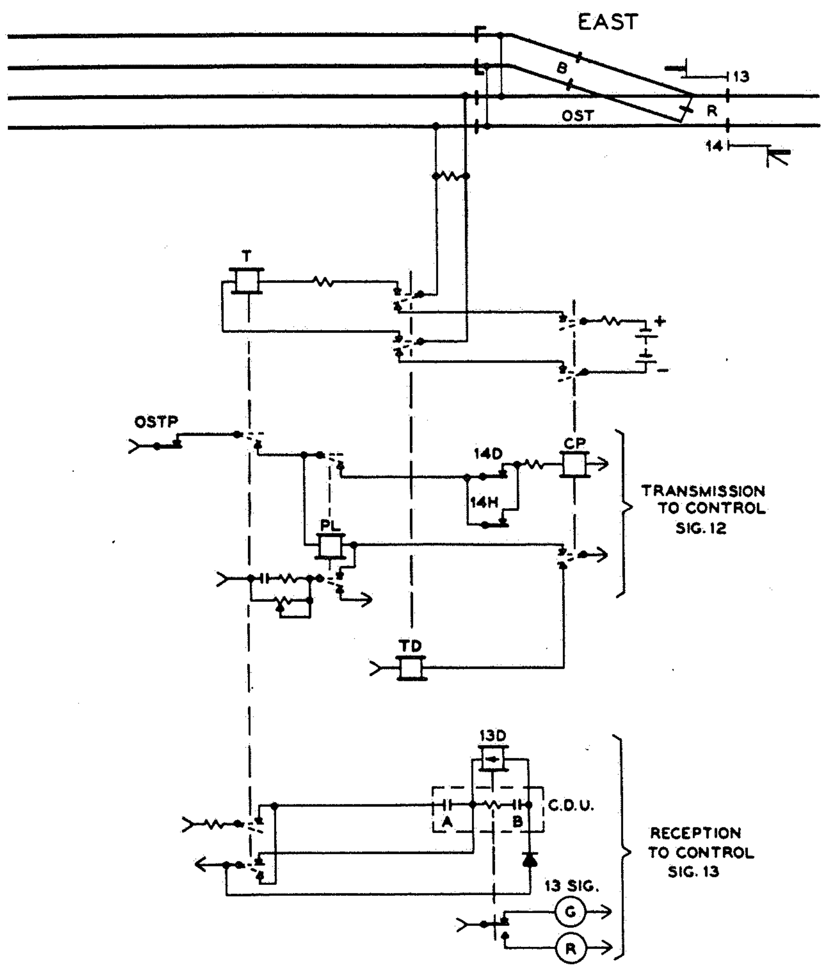


Figure 425. Simplified circuits for a siding.



Before describing the operation to clear signals 12 and 13, it may be convenient to list the relays involved, and their functions:

T	—Track relay, for reception of the pulses. This is a quick-acting polar-biased relay (Type VTB) having either one or two armatures, depending on the code requirements. One armature responds to positive pulses and the other to negative.
TD	—Transfer delay relay, which provides a time delay between the transmission of a pulse and the connecting of the track relay to the rails for receiving a pulse. This delay allows the induced rail potential to dissipate through the track ballast and bleeder resistor before the track relay is connected to the rails, so it will not be falsely energized.
CP	—Code repeater relay, which combines with the PL relay to generate the pulses, with polarity as determined by the position of the signal. This is a quick-acting polar-biased relay (Type VTB) with double armatures, if required. When two armatures are used, one armature creates positive pulses and the other negative.
PL	—Pulse length relay, which determines the length of each pulse with the aid of the CP relay. It also determines the length of the off time between pulses with the aid of a condenser-resistor unit. This is a Type CR, code-responsive, relay.
H&D	—Home and distant signal control relays. Although H relays are not shown in Figure 425, they are included here for future reference in Figure 427. These are neutral biased relays which determine the aspect of the signal, H relay controlling it to yellow, and D relay controlling it to green.

OSTP—OS track repeater relay, which repeats the position of the track relay in a detector track circuit, that is, it is normally picked up unless the detector track is occupied.

Transmission

The control of signal 13 depends upon the position of signal 11, which is clear. Therefore, pulses are being transmitted from the latter location at the west end of the siding. In this instance, the CP relay has a single armature since only pulses of one polarity need be transmitted to control a two-position signal, the stop position being absence of code.

The circuit to energize the CP relay is traced from positive energy through:

1. Front contact of OSTP relay, to check that the detector track is unoccupied.
2. Back contact of the track relay T to check that reception is not taking place. This contact also conditions the PL relay to be ready for transmission after a pulse has been received.
3. Back contact of the pulse length relay for reasons given below.
4. Front contacts of 11D and 11H relays in multiple, which determines that a pulse is to be transmitted.

The closing of the CP front contact picks up the PL relay, and at the same time releases the TD relay. This completes connections through TD back contacts to battery, thus applying positive energy to the rails. The pickup of PL removes energy from the CP relay. The TD releases quickly each time the CP picks up to transmit a pulse, then slowly picks up when CP releases to connect the track relay to the rails for reception.

Pulse Timing

The timing operation starts when the PL relay picks up. It is maintained in this position by the discharge of the condenser in a local circuit that includes a PL stick contact and a back contact of the track relay. Before the condenser charge is dissipated, the track relay receives a pulse and picks up. (This happens in dependent coding only. If the pulse were not received, the condenser charge would dissipate entirely and independent coding would commence.) The PL relay thereupon releases, allowing the condenser to recharge. The condenser and limiting resistor are in parallel with a relatively high resistance, which is adjusted to give the desired time constant.

The release of the PL relay again energizes the CP, which thereupon releases the TD and closes its own front contacts to apply energy to the rails. At the same time, the pickup of CP completes a circuit energizing the PL relay again.

The condenser charge keeps the PL picked up in the time *between* the pulses, or the off time. The code pulses are made rather short in duration (a fraction of a second) whereas the time between successive pulses is much longer (about two seconds) than the pulses themselves.

The intermittent pickup and release of the CP relay is continued as long as the detector track is unoccupied, reception is taking place at the proper time, and signal 11 is at either green or yellow aspect.

Decoding

At the east end of the siding, Figure 425, the pulses to control signal 13 are received by the track relay T, through front contacts of the TD relay. Each time the T relay picks up, it connects condenser A in the code detecting unit to energy and charges it. Each release of the T relay between transmitted pulses closes a circuit that permits the condenser to discharge through the winding of 13D relay.

The path of the current under both conditions, to keep the relay energized, is illustrated in Figure 426. In the upper diagram the arrows show the direction of current flow when the track relay picks up. The 5000 mfd. condenser **A** is charged by a circuit through the connection between terminals 2 and 3. The previously charged condenser **B**, which is 1000 mfd., is discharged through the relay winding and keeps the relay picked up during the time a pulse is received. The rectifier prevents condenser **B** from discharging through a front contact of **T** relay.

In the lower diagram, the arrows show the direction of current flow in an interval between successive pulses when the **T** relay is released. Condenser **A** discharges through the relay winding, the polarity of current being such that the biased-neutral relay is energized to keep it picked up. A parallel circuit charges condenser **B** at the same time.

Thus, in the short interval when a pulse is received, the relay is energized by condenser **B** and in the longer interval between pulses, is energized by condenser **A**. If coding ceases, the condensers will not be charged and the relay will release. If steady energy is received inadvertently from the rails, the track relay will pick up and stay up. However, condenser **A** will not be permitted to discharge, and the relay will release when the charge of condenser **B** is dissipated. This provides protection against storage-battery effect in the track.

The **D** and **H** signal control relays used in such decoding circuits are biased neutral as a precaution against possible breakdown of the condensers.

Independent Coding

The description thus far has dealt with dependent coding, that is, the track relay must pick up and release the **PL** relay so the condenser may be charged for the next transmission, which will start when the track relay releases. However, if a pulse is not received in the predetermined length of time, independent transmission takes place.

Referring to Figure 425, assume an eastbound train occupies the detector track at the west end of the siding. The **OSTP**

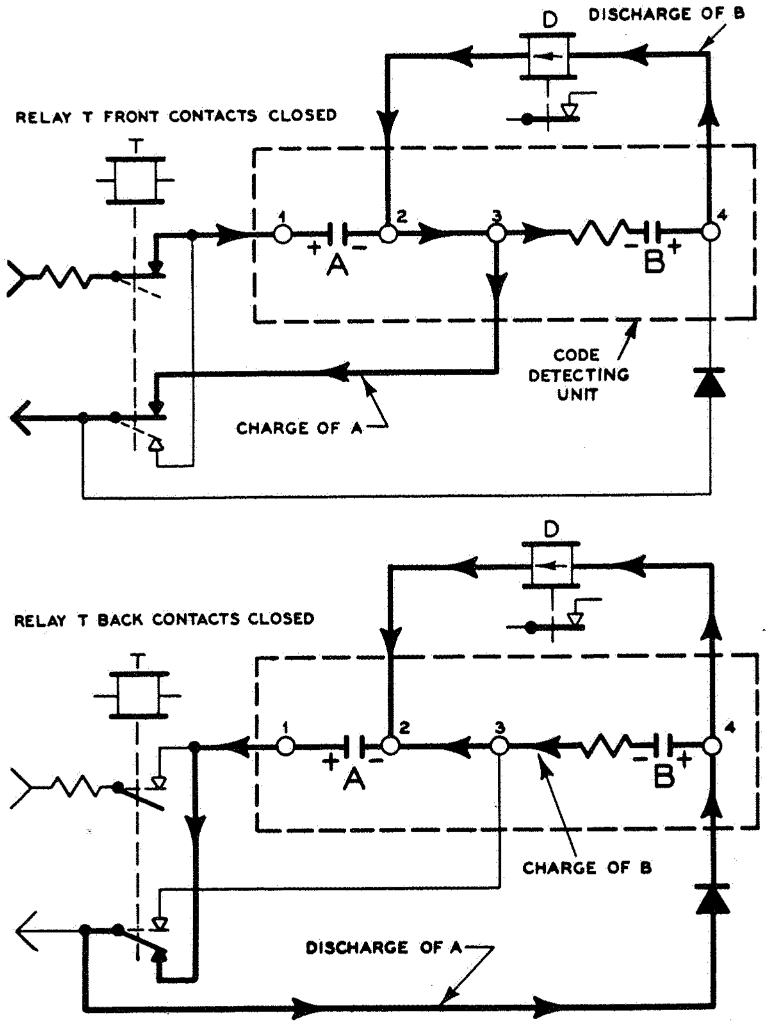


Figure 426. Decoding operation.

relay releases and prevents further operation of the **CP** relay. Hence transmission stops.

At the other end of the track circuit, the track relay remains released, so the pulse length relay **PL** is held picked up until the condenser charge is dissipated. Its release closes the pickup circuit for the **CP** relay. The transmission operation proceeds as described before, except that the track relay is inoperative and the discharge time of the condenser determines when the next pulse is to be transmitted.

At the west end of the siding, when the train leaves the detector track the **OSTP** relay picks up and allows signal 11 to clear. Thus the pickup circuit of the **CP** is again established and pulses are independently transmitted up to the rear of the train.

When traffic conditions return to normal, transmission at both ends is quickly brought into step for dependent coding. To facilitate this, the rate of independent coding at one end is different from the rate at the other end, for example, 33 pulses per minute as compared to 29 pulses per minute. The faster rate has an opportunity to be received at the other end and return the system to dependent coding.

CONTROL OF 3-POSITION SIGNALS

The circuits in Figure 427 are a continuation of those for the siding. They will serve to show how both positive and negative pulses are transmitted and received to control three-position signals. For example, information about signal 13 is transmitted eastward to control intermediate signal 15, and signal 14 is controlled by transmitting information west concerning signal 16.

In this case, the **CP** relay and the track relay have double armatures, one responding to positive pulses and the other to negative. Otherwise the operation is much the same as described previously.

In transmission to control signal 15, the circuit to energize

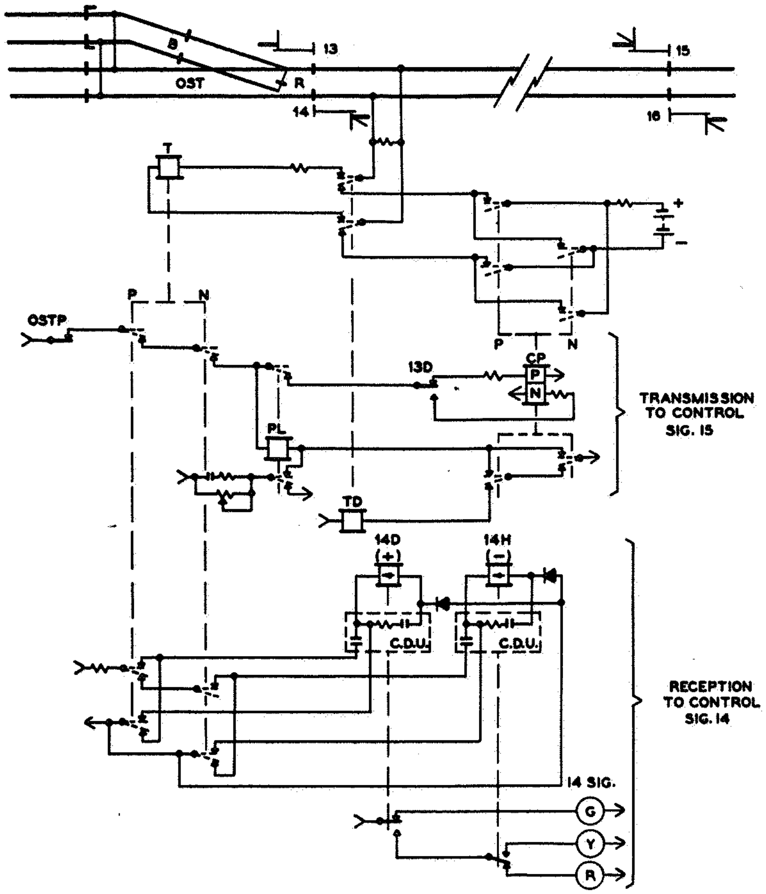


Figure 427. Circuits to control 3-position signals.

the CP is the same as before except that closing the front contact of signal control relay 13D will operate the positive armature of CP relay, and the release of 13D operates the negative armature. Therefore, when 13 signal is green, a positive pulse is transmitted to control 15 signal to green, and when 13 is red, a negative pulse is transmitted to control 15 to yellow. Occupancy of the detector track circuit will, of course, release OSTP relay, place all opposing signals at stop, and start independent coding as shown in Diagram C, Figure 423.

In the decoding operation to control signal 14, the position of signal 16 determines whether a positive or negative pulse will be received, and therefore, which armature of the track relay will operate. If the pulses are positive, signal control relay 14D picks up and remains up in the same manner described previously, and signal 14 will be green. If negative, 14H relay is energized, and signal 14 is yellow.

INTERMEDIATE SIGNAL LOCATION

Figure 428 shows the circuits for a double intermediate signal location. In addition to the relays discussed so far, others are required for direction control purposes:

AR—Series approach relay, which repeats the code when a train is approaching, and thereby picks up the proper directional stick relay. This relay has two windings, one for each direction.

S —Directional stick relay, with prefix denoting east or west. In picking up, this relay records the direction of a train passing an intermediate signal location.

FS —Traffic stick relay, with prefix denoting east or west. One of these normally energized relays is required for each intermediate signal. When a train enters the block between sidings, all the opposing traffic stick relays are released, thus establishing the direction at all locations in the block.

With the signals clear as shown, positive pulses are being transmitted dependently. A pulse received by the track relay WT, for example, applies energy to the ECP relay, so that the pulse is repeated into the adjacent track circuit. The reception of a negative pulse will usually result in transmission of a positive pulse. The impulse is always passed on, but its character may be changed, since this depends upon the position of the signal. The ECP pickup circuit to relay the pulse is taken through back contacts of the ET to check that reception is not taking place, through back contacts of directional stick relays ES and WS to check that there is no traffic, and through the positive or negative front contacts of WT to positive coil of ECP.

This operation is a simple repeat of the pulse received; there is no pulse timing involved in dependent coding. In like manner, the reception of a pulse by ET will cause WCP to transmit through a circuit similar to that described.

When a train enters the block between sidings, the tumble-down feature of Trakode places all opposing signals in the block at stop. Assume an eastbound train enters the block in which the intermediate signals W and E are located and signal W therefore goes to stop.

The release of the control relay WD opens the holding circuit of the opposing traffic stick relay WFS, which thereupon releases. Nothing happens now until the train is close enough to the location so the shunt current becomes large enough to start the approach relay coding. The initial pickup of AR energizes the directional stick relay ES which is then held picked up as the AR (E) contact operates, because of the condenser-resistor shunt making it slow-release. This ES pickup circuit checks that the opposing directional stick WS is released and its own traffic stick EFS is picked up.

As the train passes the intermediate location, the signal con-

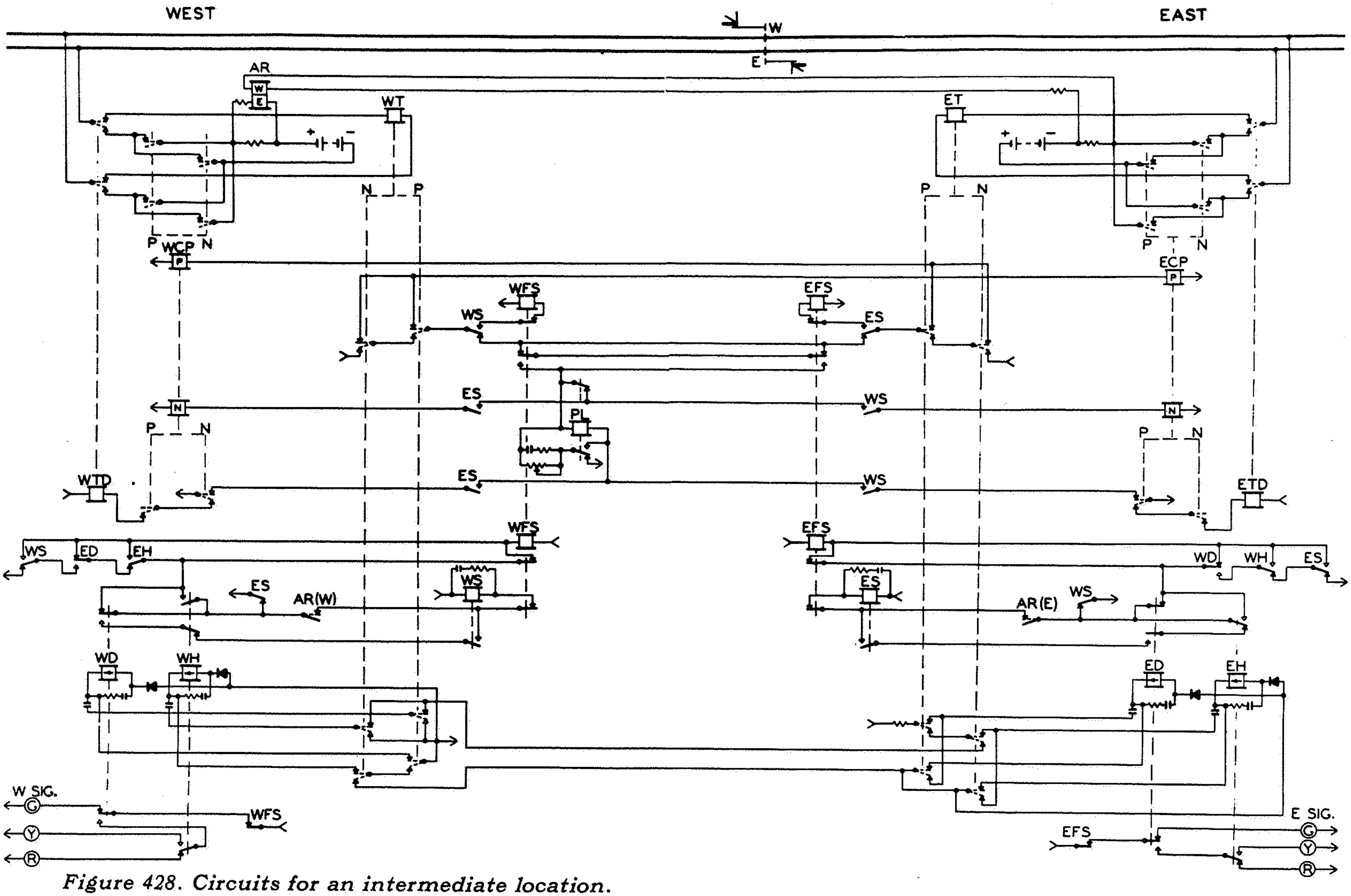

WEST
EAST
W
E
AR
W
E
WT
ET
+
−
N
P
P
N
P
WCP
N
P
ECP
N
WFS
EFS
WS
ES
ES
WS
PL
N
N
P
N
P
N
ES
WS
WTD
ETD
WFS
EFS
WS
ED
EH
WD
WH
ES
ES
AR(W)
WS
ES
AR(E)
WS
WD
WH
ED
EH
W SIG.
G
Y
R
WFS
E SIG.
EFS
G
Y
R

Figure 428. Circuits for an intermediate location.

trol relay ED releases placing signal E at stop. This establishes a stick circuit for the ES relay, by-passing the AR (E) contact, through back contacts of the ED and EH relays.

When the train is past the location, the WCP transmits negative pulses west to place the signal in the rear at yellow for a following move. With the ES picked up and WFS now released, as described, a circuit is completed to energize the negative coil of WCP relay. This can be traced from positive energy through back contacts of WT, to check that reception is not taking place, through contacts of WS released and EFS picked up, for reasons given before, through back contacts of WFS and PL relays, through a front contact of ES, and through the WCP negative coil to negative energy.

At the same time that WCP is energized to apply the negative pulse to the rails, parallel paths of the circuit pick up the pulse length relay PL immediately after charging the condenser associated with it. The pickup of PL opens the circuit to end the pulse and permits the condenser to discharge through the PL winding, holding it energized a predetermined length of time. When the charge is dissipated, PL relay releases and the WCP negative coil is again energized.

The independent coding continues until the train clears the track circuit to the east of the location.

With the train out of this block, negative pulses will be transmitted west to control signal E to yellow, and positive pulses to control the next following signal to green. Track relay ET responds to the negative pulses by operating the N contacts. These pulses are decoded in the usual manner, described previously, so that signal control relay EH is picked up and stays up as long as coding continues. Thus signal E is placed at yellow. A front contact of traffic stick relay EFS is in the signal lamp circuit so that the signals are lighted only in the direction of traffic. Reception of the negative pulses also energizes the positive winding of the WCP relay, thereby transmitting positive pulses westward to control the next signal to green.

When relay EH picks up to control E signal to yellow, the stick circuit of the ES relay is opened and this relay returns to its normal released position. Traffic stick relay WFS is picked up and restored to normal when the train clears the next signal and WD relay picks up to clear W signal. All the stick relays at this location have now been returned to normal.

REPEATING CUT SECTIONS

Where signals are spaced so far apart that the distance between them is greater than the practical operating length of Trakode, it is necessary to introduce one or more code-repeating cut sections between the signals.

Two track relays having double armatures are used at each cut section. Pulses are received by one track relay on condition that the other is not receiving pulses from the opposite direction. The relay receiving the pulse then operates its positive or negative armature in response to the polarity of the pulse, and in so doing, applies the same battery polarity to the rails in the adjacent track circuit.

BLOCK SIGNALING ADJUNCTS

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    - Line Break Circuit 502
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  - Hand-Operated Switch Machine 503
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SWITCH DETECTION AND LOCKING

Several methods and devices are used to detect the position of switch points and to lock them in position. Regardless of the method or device used, the object is safe operation of trains over switch points in signaled territory, including interlockings.

SWITCH CIRCUIT CONTROLLERS

A switch circuit controller is a device which is commonly either a part of or used with a switch operating mechanism. It is operated by a rod connected to the switch. The controller indicates that the switch point is within a specified distance of the stock rail.

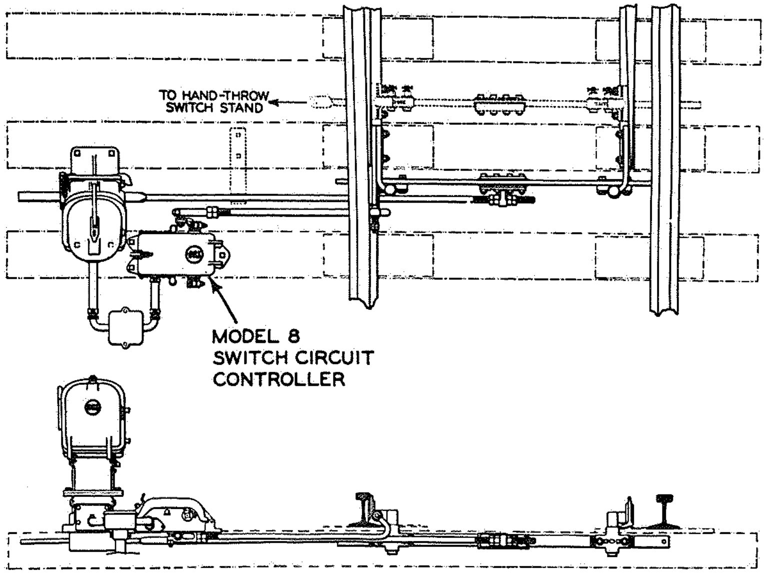


Figure 501. G-R-S Model 8 switch circuit controller and Model 9B electric switch lock applied to a hand-throw switch.

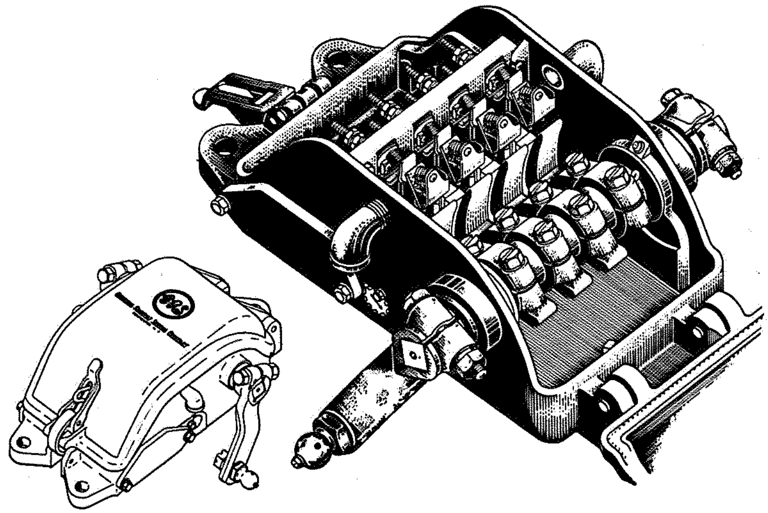


Figure 502. Model 8 switch circuit controller.

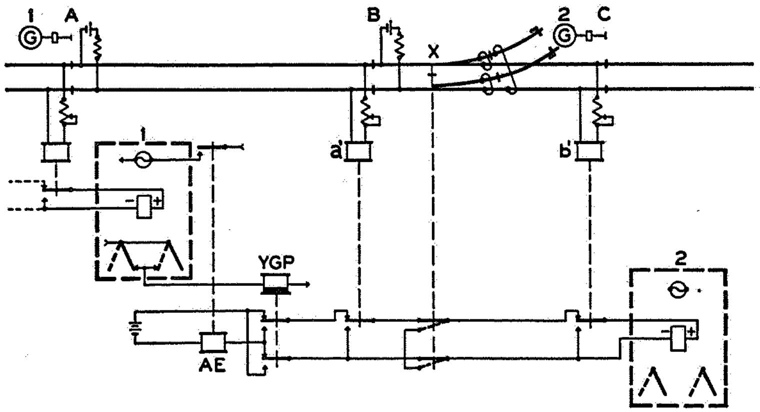


Figure 503. Simplified circuit of 2-block, 3-indication signaling with polarized line circuit, showing typical application of switch circuit controller.

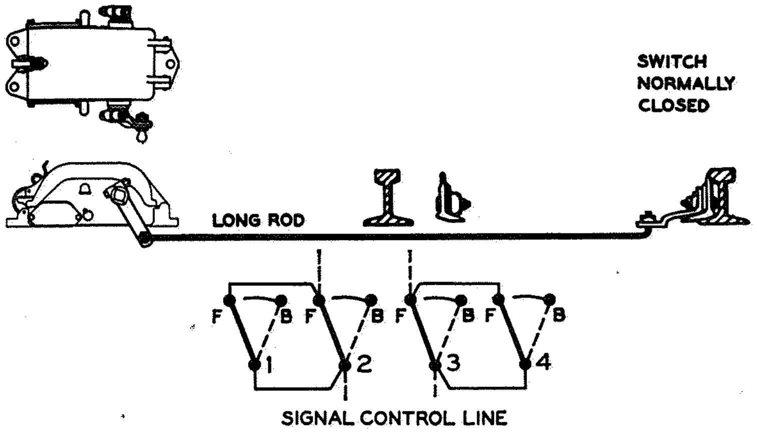

SWITCH NORMALLY CLOSED
LONG ROD
F
B
F
B
F
B
F
B
1
2
3
4
SIGNAL CONTROL LINE

Figure 504. Typical line break circuit and switch layout when controller is located on the normally open point side of the switch.

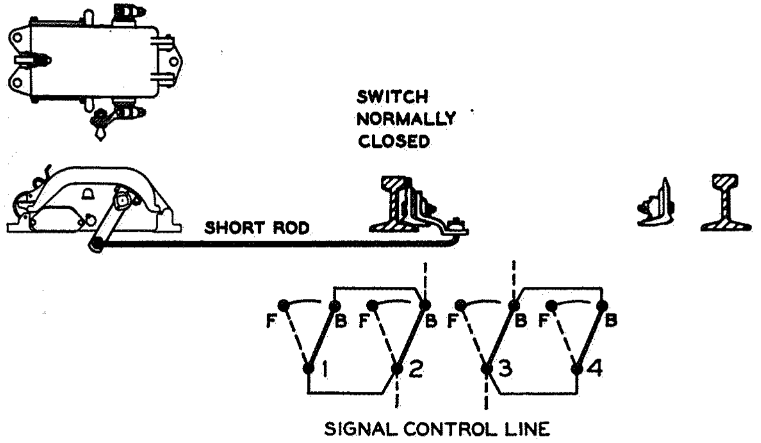
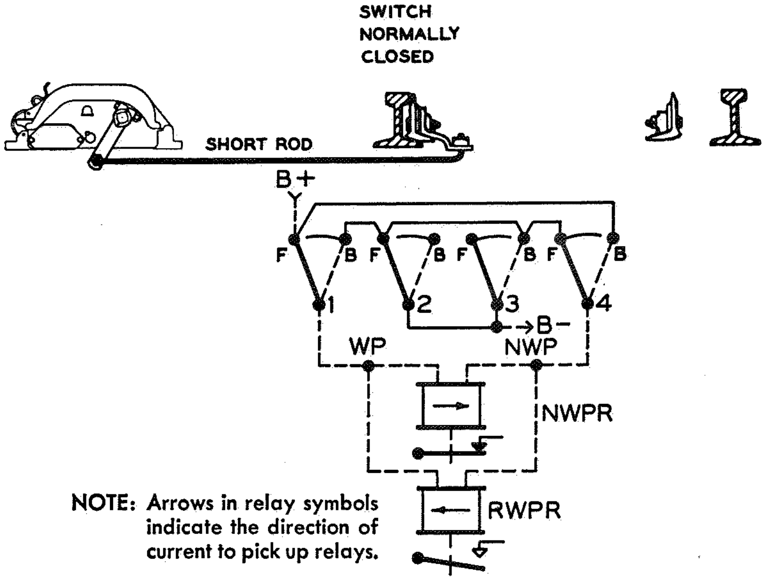

SWITCH NORMALLY CLOSED
SHORT ROD
F
B
F
B
F
B
F
B
1
2
3
4
SIGNAL CONTROL LINE

Figure 505. Typical line break circuit and switch layout when controller is located on the normally closed point side of the switch.


SWITCH NORMALLY CLOSED
SHORT ROD
B+
F
B
F
B
F
B
F
B
1
2
3
4
→B−
WP
NWP
NWPR
RWPR

NOTE: Arrows in relay symbols indicate the direction of current to pick up relays.

Figure 506. Typical polarized switch repeater circuit using biased-neutral relays, shown with controller located on normally closed point side of the switch.

Figure 501 shows a G-R-S Model 8 switch circuit controller as it would be installed with a hand-throw switch. When the hand-throw switch is operated, a rod connected between the switch points and the crank on the switch circuit controller moves the contacts within the controller, Figure 502, to affect the associated signal circuit.

Line Break Circuit

The circuit in Figure 503 shows an application of a controller in automatic block signaling. This circuit detects the condition of the track between signal 1 and signal 2. This is accomplished by breaking the control wires through contacts on the track relays a′ and b′ and on switch circuit controller x. Whenever any of these contacts are open, signal 2 will indicate stop. Figures 504 and 505 show how such an arrangement is actually wired.

Polarized Switch Repeater Circuit

The circuit shown in Figure 506 uses switch repeater relays to reflect the position of the switch points. NWPR and RWPR are biased-neutral relays. They will pick up only when current is flowing in the proper direction through their coils, as indicated by the arrows.

HAND-OPERATED SWITCH MACHINE

Circuit controllers, in addition to a switch operating mechanism and a facing point lock, are included in the G-R-S Model 9 hand-operated switch machine, Figure 507.

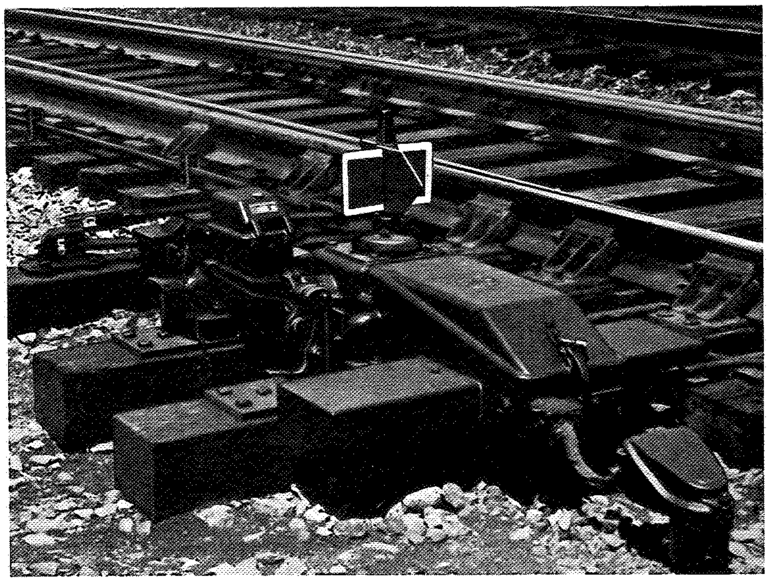


Figure 507. G-R-S Model 9 hand-operated switch machine with a Model 10 electric switch lock.

Built-in circuit controllers, one normal and one reverse, check both switch position and locking. Contacts latch in "switch unlocked" position if the switch is accidentally trailed through when positioned normal.

FACING POINT LOCK

A facing point lock is a mechanical lock for a switch, derail, or movable point frog, comprising a plunger stand and a plunger which engages a lock rod attached to the switch point to lock the operated unit.

The G-R-S Type A facing point lock, Figure 508, is especially designed to provide complete interlocking protection for all types of spring switches. All spring switch operating features are retained.

The Type A facing point lock consists of two basic units, Figure 509, an escapement mechanism and a lock mechanism.

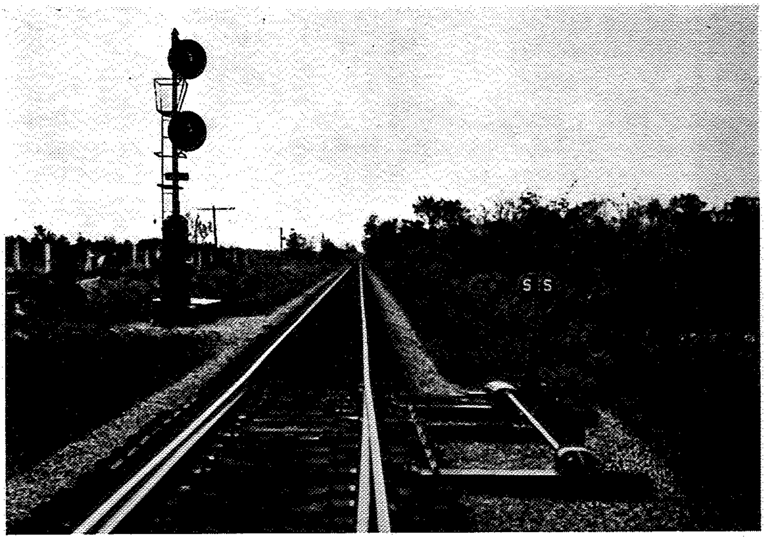


Figure 508. Type A facing point lock.

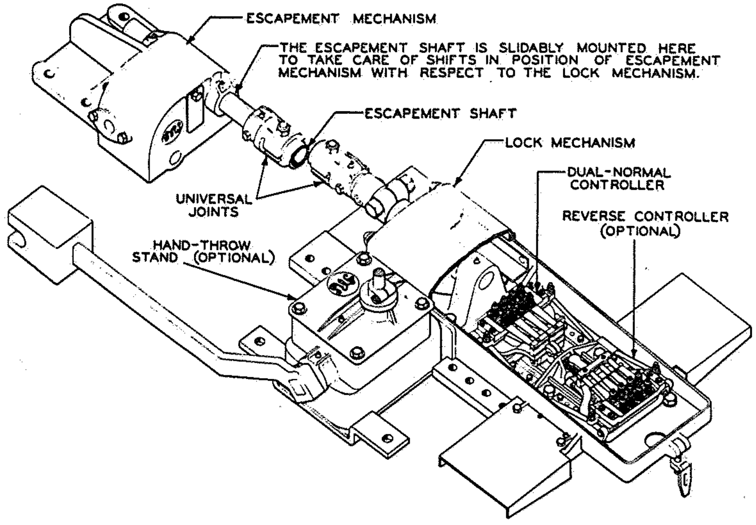

ESCAPEMENT MECHANISM
THE ESCAPEMENT SHAFT IS SLIDABLY MOUNTED HERE TO TAKE CARE OF SHIFTS IN POSITION OF ESCAPEMENT MECHANISM WITH RESPECT TO THE LOCK MECHANISM.
ESCAPEMENT SHAFT
LOCK MECHANISM
DUAL-NORMAL CONTROLLER
REVERSE CONTROLLER (OPTIONAL)
UNIVERSAL JOINTS
HAND-THROW STAND (OPTIONAL)

Figure 509. Type A facing point lock equipped with reverse controller and hand-throw mechanism.

It can be unlocked manually or automatically. Operating the hand-throw lever removes the locking plunger from the lock rod and throws the switch. During automatic unlocking, which occurs when the switch is trailed, the escapement mechanism is operated by the initial deflection of the switch rail. This deflection occurs when a train trails the switch, that is, passes through it from the heel of the switch, to force the switch rail away from the stock rail. This deflection is transformed into a rotary movement of the escapement shaft which connects the escapement mechanism with the lock mechanism. In the lock mechanism, this movement withdraws the locking plunger from the lock rod, releasing the switch. Circuit controllers built into the lock mechanism operate contacts to control the signal aspects.

LIGHT-OUT PROTECTION

Rule 27 of the Standard Code of Operating Rules, Association of American Railroads, states: "A signal imperfectly displayed, or the absence of a signal at a place where a signal is usually shown, must be regarded as the most restrictive indication that can be given by that signal, except that when the day indication is plainly seen, or when sufficient lights in a position- or color-position-light signal are displayed to determine indication of the signal, it will govern."

POWER TRANSFER

Signal lamps are usually supplied a.c. from the secondary of a lighting transformer. Symbols are EBX, positive; and ENX, negative, E meaning "electric light." Should the a.c. fall below a predetermined value, power transfer relay PTR releases its armature transferring, through its contacts, the energy supply from a.c. to d.c. from a standby battery. The d-c. symbols are B for positive battery and N for negative battery.

LIGHT-OUT PROTECTION

Light-out relays provide a means of avoiding unnecessary stops by displaying a secondary indication should a signal lamp burn out. This secondary indication may be provided by the regular light unit next more restrictive to the one whose lamp is burned out, as shown in Figure 510, or by an auxiliary light unit.

Hot Filament Check, Color-Light Signal

In Figure 510, EBX is normally fed through a front contact of PTR, front contacts of signal control relays HR and DR, the rectifier and coils of light-out relay LOR, to the green (G) signal lamp, returning to ENX via another front contact on PTR.

Obviously, the light-out relay must be capable of operation on either a.c. or d.c. The rectifier inserted in multiple with the windings of LOR passes a.c. in one direction only. The a.c. will, on one half of the sine wave, be blocked by the rectifier and

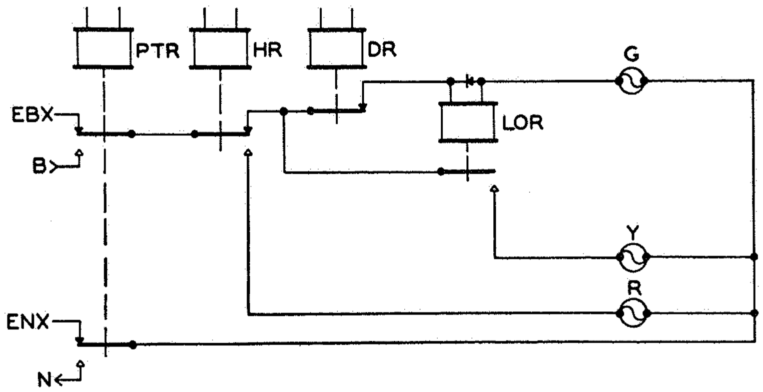

PTR
HR
DR
G
EBX
B
LOR
Y
R
ENX
N

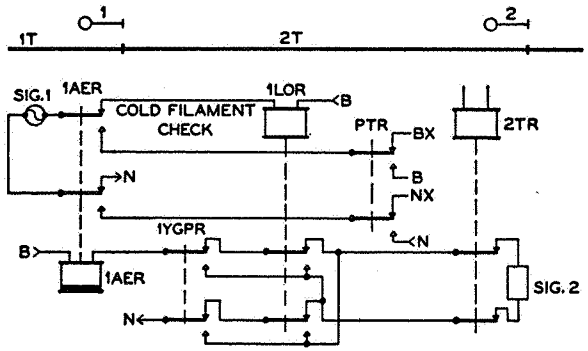
Figure 510. Typical circuit for light-out detection with color-light signals. Burned out green filament causes yellow lamp to light. Hot filament check.

will flow through the windings of LOR, thus energizing the relay. During the other half of the sine wave, however, current will pass through the rectifier. In case of transfer to battery operation, d.c. is blocked by the rectifier and flows through the windings of LOR. When the green (G) lamp burns out, energy to LOR is cut off entirely and it will drop, closing its back contact to transfer energy to the yellow (Y) lamp, the next most restrictive indication. The circuit in Figure 510 is a hot filament check, that is, the LOR is checking a normally lighted signal.

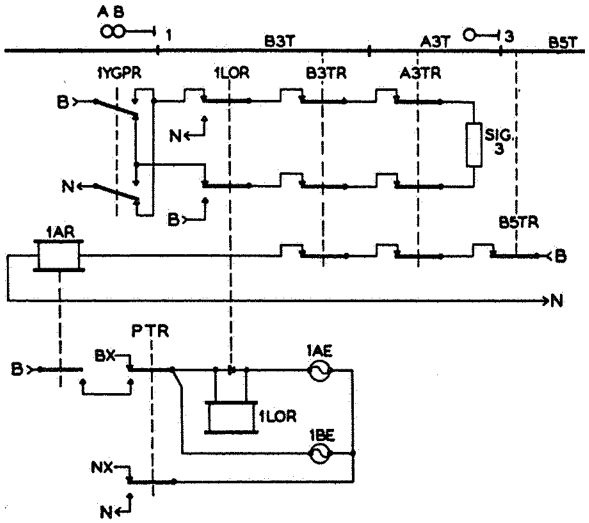
Cold Filament Check, Searchlight Signal

The circuits in Figure 511 are for light-out protection with G-R-S searchlight signals.

The circuit in Figure 511a utilizes the LOR relay to check a cold filament. The signals are normally not lighted. The light-out relay checks that the lamp filaments have not broken due to vibration or other causes. It is cut out of the circuit when a train arrives on the approach to the signal, dropping approach lighting relay AER. EBX is fed through a front contact on PTR,


1
2
1T
2T
SIG.1
1AER
COLD FILAMENT CHECK
1LOR
B
PTR
BX
2TR
N
B
NX
1YGPR
N
B
1AER
SIG. 2
N

a. A burned out filament in signal 1 causes signal 2 to display YELLOW. Cold filament check.


A B
1
B3T
A3T
3
B5T
1YGPR
1LOR
B3TR
A3TR
B
N
SIG. 3
N
B
B5TR
1AR
B
N
PTR
B
BX
1AE
1LOR
1BE
NX
N

b. A burned out filament in the top unit of home signal 1 causes approach signal 3 to display yellow. Hot filament check.

Figure 511. Typical circuits for light-out detection with searchlight signals.

a back contact on AER, signal 1 lamp, a back contact on AER to return to ENX via another front contact on PTR. Should the a-c. supply fail, the PTR transfers the lamp from a.c. to d.c. Contacts on LOR are in the control circuit for signal 2. Thus, if the filament in signal 1 lamp is opened, the energy to signal 2 is pole changed, and signal 2 will display yellow upon the approach of a train.

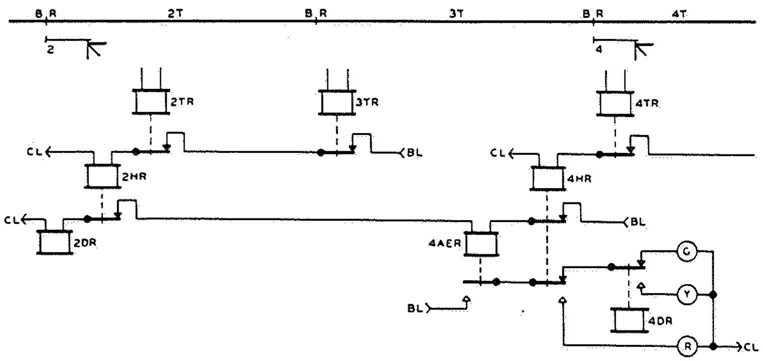
Hot Filament Check, Searchlight Signal

In Figure 511b, when lamp 1AE of signal unit 1A burns out, signal 3 will display a yellow indication, as contacts of LOR pole change the energy fed through contacts on yellow-green repeater 1YGPR and the track relays to signal 3. This circuit is arranged so that when power fails and PTR drops, signal 1 is approach lighted through a back contact on approach relay 1AR. This is done to conserve battery. This check, made with the signal lighted, is a hot filament check.

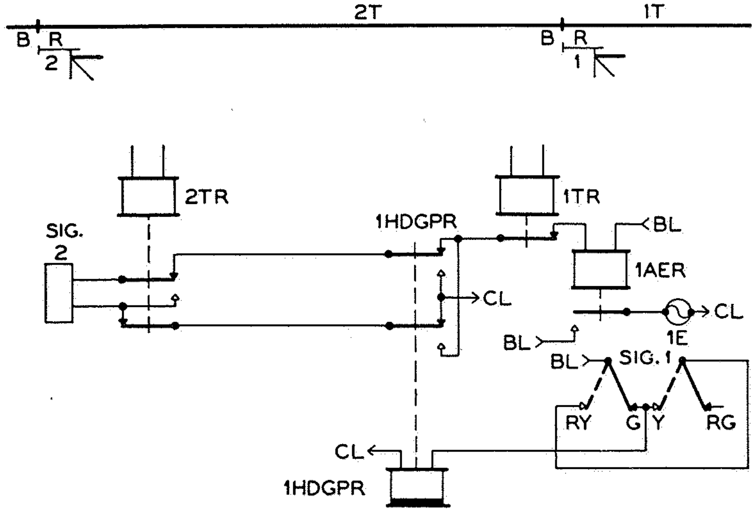
With the arrangements shown in Figure 511, the engineer would bring his train under control in the normal way rather than hurriedly when he suddenly realized that the indication of the signal he was approaching was not what past experience had accustomed him to expect. Thus an unnecessary emergency brake application is avoided.

Double Filaments

Double filament lamps may be used in the signals. When the high wattage filament burns out, a lower wattage filament in the same lamp envelope displays a weak aspect. Thus, when a train comes within range of the signal, the engineer sees the weak aspect and may proceed as indicated. This eliminates a stop and enforement of Rule 27. Trainmen are expected to report the weak aspect so the lamp bulb will be changed out.



a. Approach lighting relay in series with signal control relay.



b. Approach lighting relay in series with SA signal mechanism.

Figure 512. Typical applications of series line approach lighting relay.

APPROACH LIGHTING

It is common practice on many railroads to have the signals lighted only when a train is in the vicinity of the signal which governs its movements. Approach lighting is done for two primary reasons: (1) to conserve electrical energy when a signal indication is not necessary and (2) to convey signal indications more distinctively when a train approaches a location having many signals.

One of the simplest methods is to use an auxiliary relay at the battery end of, and in series with, a line controlled signal relay or mechanism.

Figure 512a shows a circuit with an approach lighting relay in series with the signal control relay. Should a train occupy track circuits 2T or 3T, signal control relay 2HR would drop, opening its front contact and removing energy from approach lighting relay 4AER. When 4AER drops, closing its back contact, lamp energy is applied to the signal.

Figure 512b shows a circuit with an approach lighting relay in series with a G-R-S searchlight signal mechanism. When a train arrives on track circuit 2T, the feed to 1AER is opened at 2TR front, and the back contact of 1AER closes to apply energy to signal 2 lamp 1E.

SPECIAL PROTECTIVE DEVICES

MOTOR-CAR PROTECTION

An indicator system can be applied to any signaling system using continuous track circuits. The system provides protection for the operators of motor cars by enabling them to find out whether track circuits to their rear are occupied.

There has been no satisfactory development of a shunt device for use by light cars, which would, by shunting the track, provide its own protection in setting up the necessary signals for motor-car movement. A light vehicle, due to its inherent inability to maintain the necessary contact, creates rather unsatisfactory conditions in track and other relays involved in the signal operation.

A wayside device of the light type, shown in Figure 513, is called a motor-car indicator. This term is somewhat a misnomer, since the device in no way indicates the presence or absence of a motor car, but rather indicates to the motor-car crew the presence or absence of trains in the section investigated. It is a relatively simple device, containing a lamp and a pushbutton. This device is usually used to check the track occupancy of blocks to the rear of the indicator location. By using two indicators, the blocks in both directions may be checked.

A simplified circuit and location plan is shown in Figure 514. To check whether a train is approaching, the motor-car operator presses the button in the bottom of the lamp unit. If the track circuits to the rear are unoccupied, the lamp will light. Note that only one additional wire, MCI, is required for the motor-car indicator circuit. The common serves as the other leg of the two-wire circuit.

The general principle is that a motor-car indicator relay, MCIR, is checked through the front contacts of as many track relays as it is desired to extend the control. The distance that the check circuit is taken back depends, of course, upon the geographic layout of the tracks and the operating conditions that prevail in a given territory. At locations where the common is broken, such as at signal 446, MCIR is in series with MCI and common, and is thus normally energized. The feed to the indicator lamp is taken through MCIR front contact and the normally open pushbutton.

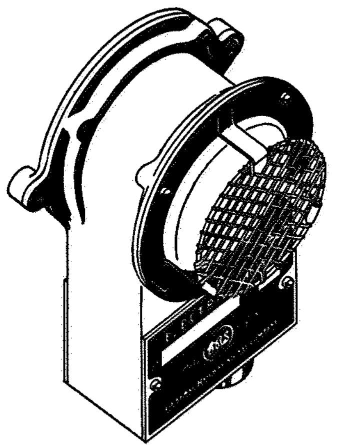


Figure 513.
Motor-car indicator.

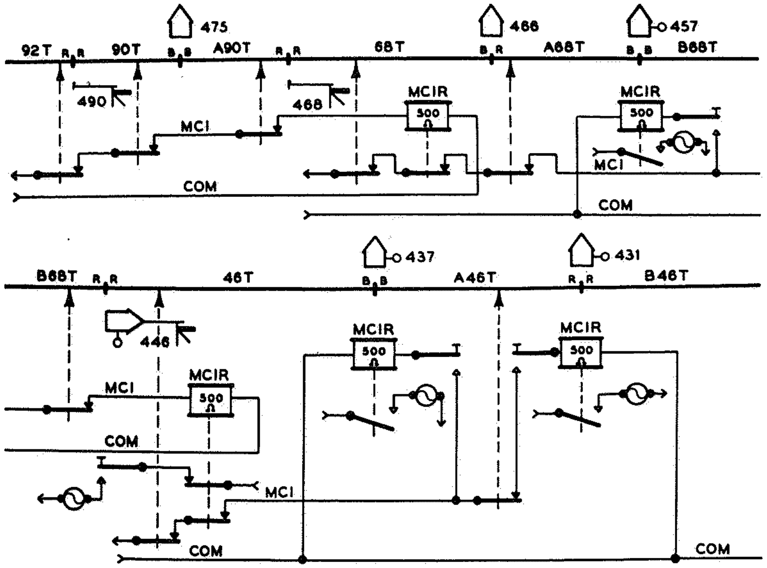

475
466
457
92T
R R
90T
B B
A90T
R R
68T
B R
A68T
B B
B68T
490
468
MCI
MCIR
500 Ω
COM
MCIR
500 Ω
MCI
COM
437
431
B68T
R R
46T
B B
A46T
R R
B46T
446
MCIR
500 Ω
MCI
MCIR
500 Ω
MCIR
500 Ω
COM
MCI
COM
COM

Figure 514. Typical motor-car indicator circuit as used with automatic block signaling.

At locations where the common is unbroken, such as at location 457, MCIR is connected across MCI and common in series with the normally open pushbutton. The indicator lamp is fed directly through the front contact of MCIR.

Signal location 468 illustrates the method of taking the control circuit past a break in the common wire at locations where an indicator lamp is not required.

SLIDE DETECTION

Slide detector fences, Figure 515, are used for protection against derailment from landslides. They protect the right-of-way through cuts, at the base of rocky slopes, and in tunnels.

Fences are constructed and located according to local conditions in the slide area. They are usually installed in sections up to 400 feet long. The usual practice is to use a five-foot, pole-suspended fence mounted from one to two feet above the ground level to allow small stones to pass under without operating the fence.

A switch circuit controller, Figure 516, is mounted on a steel mast between each fence section. The fence is loosely stapled to all intermediate fence posts to allow for lateral movement.

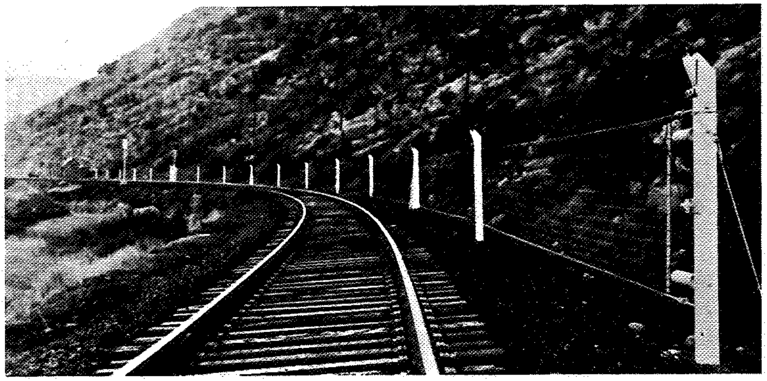


Figure 515. Slide detector fence.

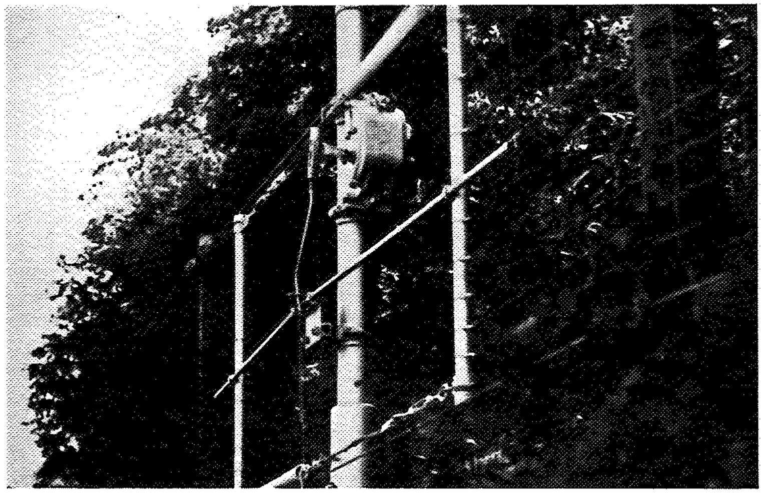


Figure 516. Circuit controller location.

When a slide occurs, the fence movement is transmitted through an operating pipe and trigger arrangement that unlatches a spring to operate the controller.

If the fence is located in automatic block territory, the controller may be included in the line circuit control. Outside automatic block territory, it may be used to control special slide warning signals.

FLOOD DETECTION

Flood detection provides signal protection for high water conditions that may be weakening bridges, undermining fill, or otherwise creating hazards.

Such systems consist of a float-operated contactor installed in locations dictated by experience. One such device, Figure 517, is so arranged that when the water reaches a predetermined level the float will rise far enough to open the contacts to put the associated signals to stop. Such devices are usually trip contacts that, once operated, must be reset manually.

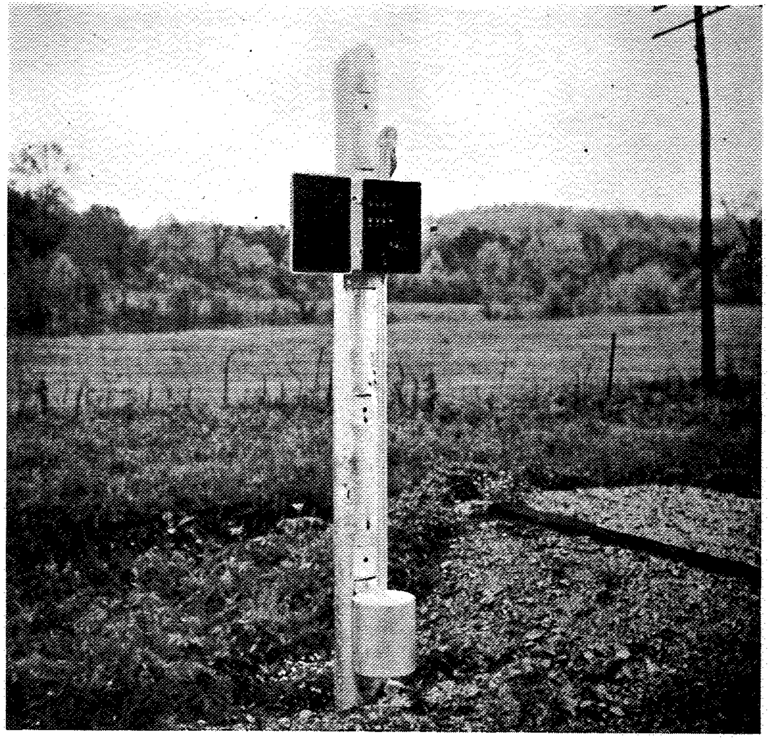


Figure 517. Flood detector.

FIRE DETECTION

Fire detection, desirable in wooden trestles, wood-lined tunnels, snow sheds, etc., usually consists of fusible wire in series with the signal circuit. This wire melts in the presence of fire, opening the signal circuit.

A circuit controller, spring loaded similarly to that shown in Figure 516, can also be used. A rope, made of some material

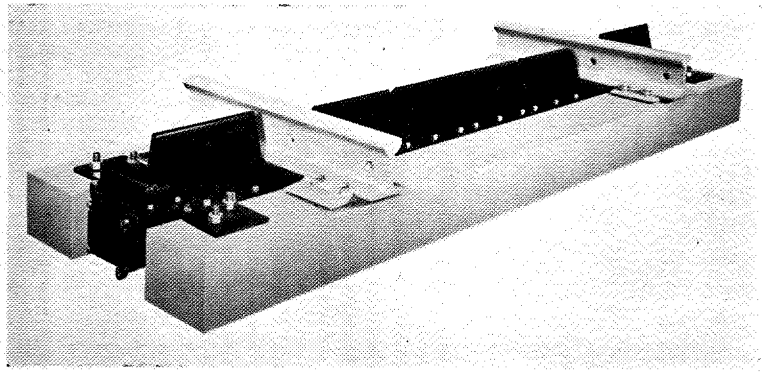


Figure 518. G-R-S self-resetting dragging equipment detector.

that will part easily when exposed to flame, is used to keep the controller contacts closed. When fire parts the rope, the spring snaps the circuit controller contacts open, thus controlling appropriate signal circuits to indicate the hazardous condition.

DRAGGING EQUIPMENT DETECTION

The G-R-S self-resetting dragging equipment detector, Figure 518, is non-directional, available for use by traffic moving either way over the tracks. It will reset itself after each operation.

The detector is used in places where dragging equipment would be especially detrimental to the movement of trains or to track devices such as switches, retarders, etc. Dragging equipment detectors are installed at the entrances to tunnels and at approaches to interlocking plants and classification yards.

The dragging equipment detector consists of a shaft supported by bearings at either end. Bearings are housed in compartments which are spring mounted on brackets fastened to the ties. Six blades, adjustable for various rail heights, are bolted to the shaft. A torsion bar extending through the shaft keeps the shaft in position so that the blades remain vertical and will return to their vertical position after having been deflected by dragging equipment.

The bearing compartment on one end of the detector houses a simple device for adjusting the torque as required. Thus the detector may be adjusted so that it will not open its contact when struck relatively light blows, as, for example, by icicles hanging from the running gear.

A normally closed contact, housed in the opposite bearing compartment, is arranged so that it will open whenever the shaft is rotated 5 degrees or more in either direction.

Figure 519 shows one way to circuit the detector at the entrance to an interlocking plant. Dragging equipment detector relay DEDR in the tower is normally fed by a multiple circuit

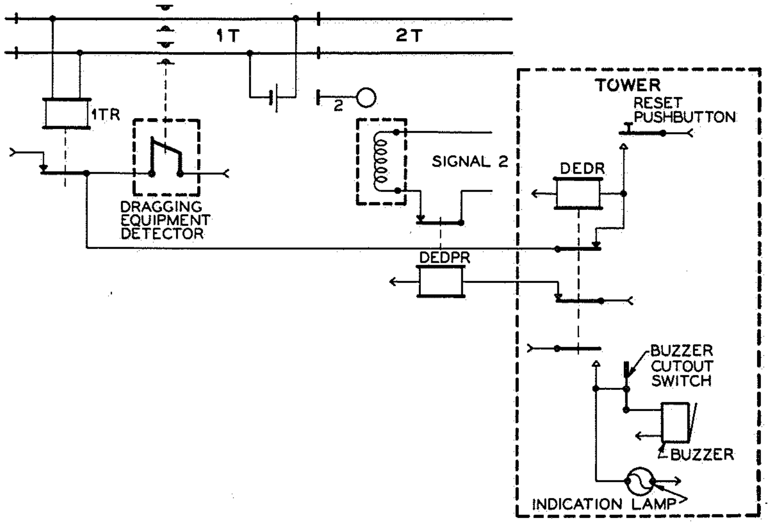


Figure 519. Simplified circuit for dragging equipment detector.

through a front contact of track relay 1TR and the normally closed contact of the dragging equipment detector. Unless there is a train on track circuit 1T, relay DEDR cannot be dropped by pushing the detector blades. This circuiting keeps pranksters from putting signal 2 to stop.

When a train with dragging equipment moves toward signal 2, 1TR will be down. As soon as the dragging parts hit the blades, the detector contact opens. Current is cut off from relay DEDR, and it opens its front contacts and closes its back contacts. Current is cut off from DEDPR, and it opens its front contacts, thus putting signal 2 to stop.

The buzzer and the indication lamp in the tower are fed current through the back contact of DEDR. To reset DEDR, the towerman simply presses the reset pushbutton.

ELECTRIC SWITCH LOCKING

Rule 513 of the Standard Code states in effect that a trainman must wait a required number of minutes before operating a switch which allows his train or engine to enter on, cross over, or foul a main track.

An electric switch lock provides a means of interlocking a manually operated switch with the signal circuits so that the switch cannot be operated unless traffic conditions permit, or unless the normally sealed emergency release is operated.

LOCKING THE LEVER

The G-R-S Model 10 electric switch lock locks the hand-throw lever of most ground-throw switch stands, Figure 520, and hand-operated switch machines, Figure 521.

The lock is operated by depressing the latch and removing the switch padlock. This action puts associated signals to stop. If traffic conditions permit, the lock coils are energized, and

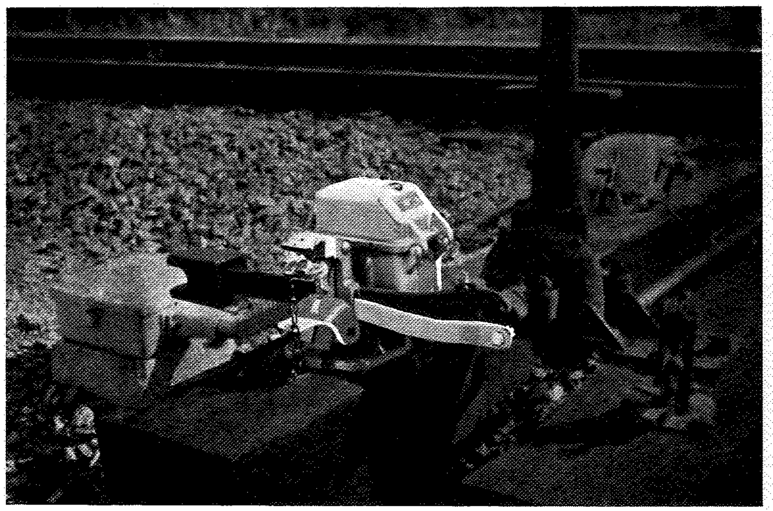


Figure 520. G-R-S Model 10 electric switch lock applied to a hand-throw switch stand.

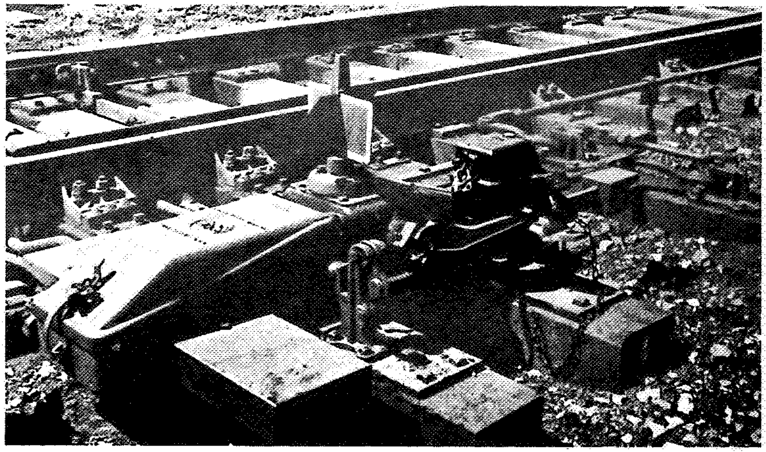


Figure 521. G-R-S Model 10 electric switch lock applied to a Model 9 hand-operated switch machine.

an indication lamp, visible through a window in the cover, lights. The lamp indicates to the trainman that the mechanism is unlocked. The pedal can now be depressed and the hand-throw lever of the switch stand operated to move the switch points.

An interlocked emergency release can be provided on the lock to be used if the switch must be unlocked when the normal circuit does not respond.

A tandem attachment, Figure 522, is available for the Model 10 lock for locking the hand-throw lever in either the normal or reverse position. The tandem lock, as used within interlocking limits, prevents a trainman from operating a hand-throw switch to either the normal or the reverse position without receiving an electrical unlock.

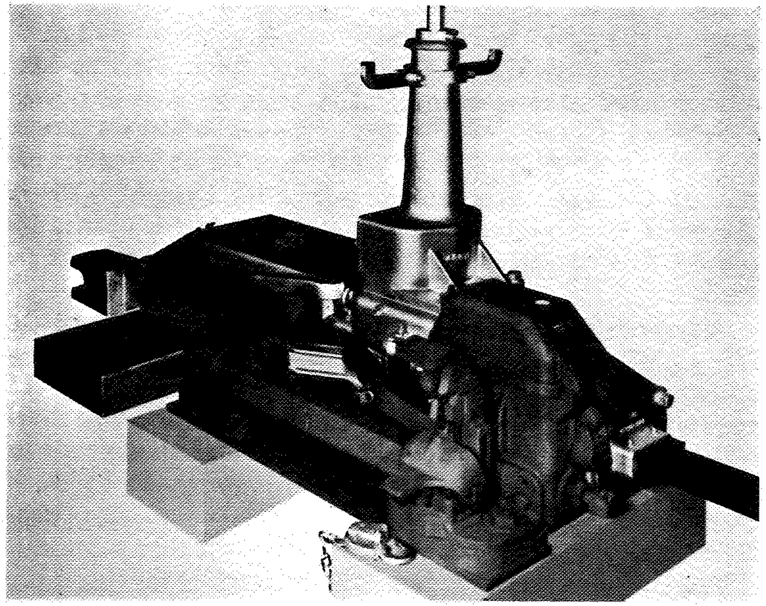
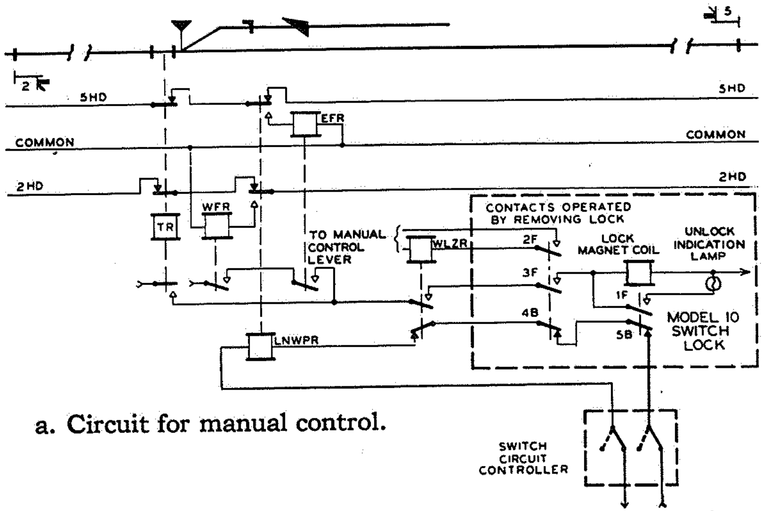


Figure 522. G-R-S Model 10 electric switch lock with tandem attachment applied to a Model 9 hand-operated switch machine.

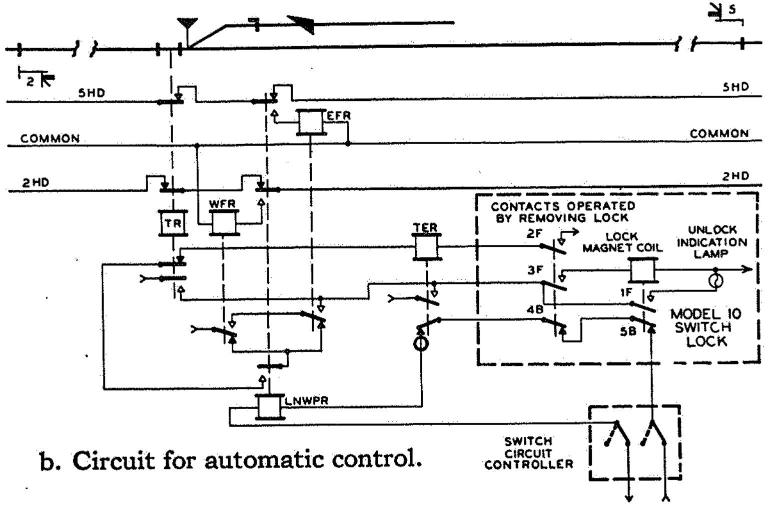
The typical circuit in Figure 523a is arranged for manual control of the Model 10 electric switch lock. Release of the lock for a move from the siding onto the main line is accomplished as follows: mechanically operated contacts 2, 3, and 4 in the lock mechanism are operated when the trainman's padlock is removed from the switch stand. Contact 4b opens the circuit to lever normal switch repeater relay LNWPR which drops, opening the line wire circuits to signal control HD relays controlling approach signals 2 and 5. Back contacts on LNWPR close circuits from the HD wires through westward and eastward traffic relays WFR and EFR to common. If traffic conditions permit, the towerman, upon being notified, energizes switch lock control relay WLZR by line wire control. Front contacts of WFR, EFR, and WLZR now establish a circuit through the lock magnet coil to release the lock. LNWPR is prevented from picking up, as its control circuit is opened by contact 5 on the lock magnet as well as by a back contact on WLZR.

Release of the switch lock for a move onto the siding is as follows: with a train standing in the track section, which de-energizes track relay TR, and with WLZR energized by the towerman, energy is fed through a back contact on TR, front contact on WLZR, and mechanically operated contact 3F to the lock magnet coil. In this case the front contacts on WFR and EFR are bypassed, as the train has automatically established its block protection.

The typical circuit in Figure 523b is arranged for automatic control of the Model 10 electric switch lock. For a move onto the main line, the trainman, as with manual control, removes the padlock, opening the mechanically operated contacts and


2
5
5HD
COMMON
2HD
EFR
WFR
TR
TO MANUAL CONTROL LEVER
WLZR
LNWPR
CONTACTS OPERATED BY REMOVING LOCK
2F
3F
4B
1F
5B
LOCK MAGNET COIL
UNLOCK INDICATION LAMP
MODEL 10 SWITCH LOCK
SWITCH CIRCUIT CONTROLLER

a. Circuit for manual control.


2
5
5HD
COMMON
2HD
EFR
WFR
TR
TER
LNWPR
CONTACTS OPERATED BY REMOVING LOCK
2F
3F
4B
1F
5B
LOCK MAGNET COIL
UNLOCK INDICATION LAMP
MODEL 10 SWITCH LOCK
SWITCH CIRCUIT CONTROLLER

b. Circuit for automatic control.

Figure 523. Typical application circuits showing the Model 10 switch lock applied to absolute permissive block signaling.

dropping LNWPR. If there are no trains approaching either signal 2 or 5, WFR and EFR traffic relays will pick up and energize the lock magnet coil through mechanically operated contact 3F. If either traffic relay, however, is deenergized, indicating that a train is approaching, time element relay TER will be energized, the circuit being through WFR or EFR back, LNWPR back, TR front, the coil of TER, and mechanically operated contact 2F. This circuit thus prevents the trainman from getting a release until time has elapsed to permit an approaching train to obey the stop signal.

For a movement onto the siding, the track relay will be down, and a circuit completed through mechanically operated contact 3F to energize the lock magnet coil.

LOCKING THE LOCK ROD

The G-R-S Model 9B electric switch lock, Figure 524, locks the lock rod on a switch. It may be used to lock the lock rod in one position only, or, when equipped with a double adjustable lock rod, it may be used to lock the lock rod in both the normal and reverse positions. The lock may also be used to lock any device which can be locked with a lock rod—tunnel doors for example.

The lock, Figure 525, consists essentially of a locking plunger, that can be raised or lowered by a hand crank, and an electromagnet which lifts a locking key from a notch in a locking dog. The movement of the hand crank is normally blocked by the electrically actuated locking key so the trainman cannot raise the plunger out of the lock rod if the lock coils are not energized.

Figure 526 shows a typical switch lock control circuit with emergency release and normally deenergized approach relays. The broken lines indicate additional circuiting for optional supervisory control. Release of the lock for a move onto the main line is accomplished as follows: when the trainman makes

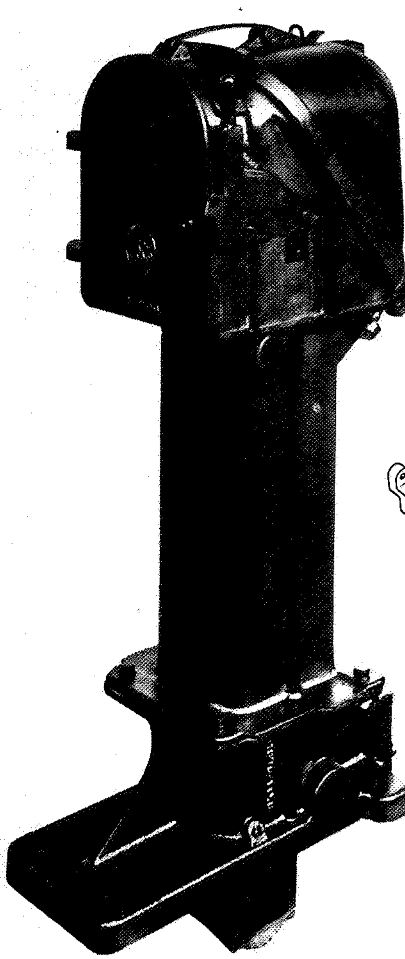


Figure 524. The Model 9B electric switch lock.

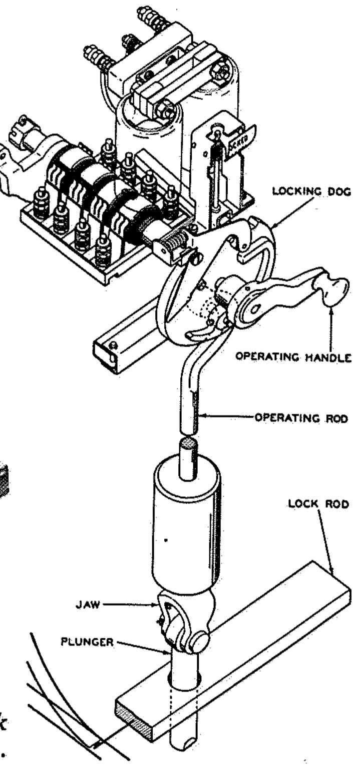

LOCKING DOG
OPERATING HANDLE
OPERATING ROD
LOCK ROD
JAW
PLUNGER

Figure 525. Model 9B lock operating rod and plunger.

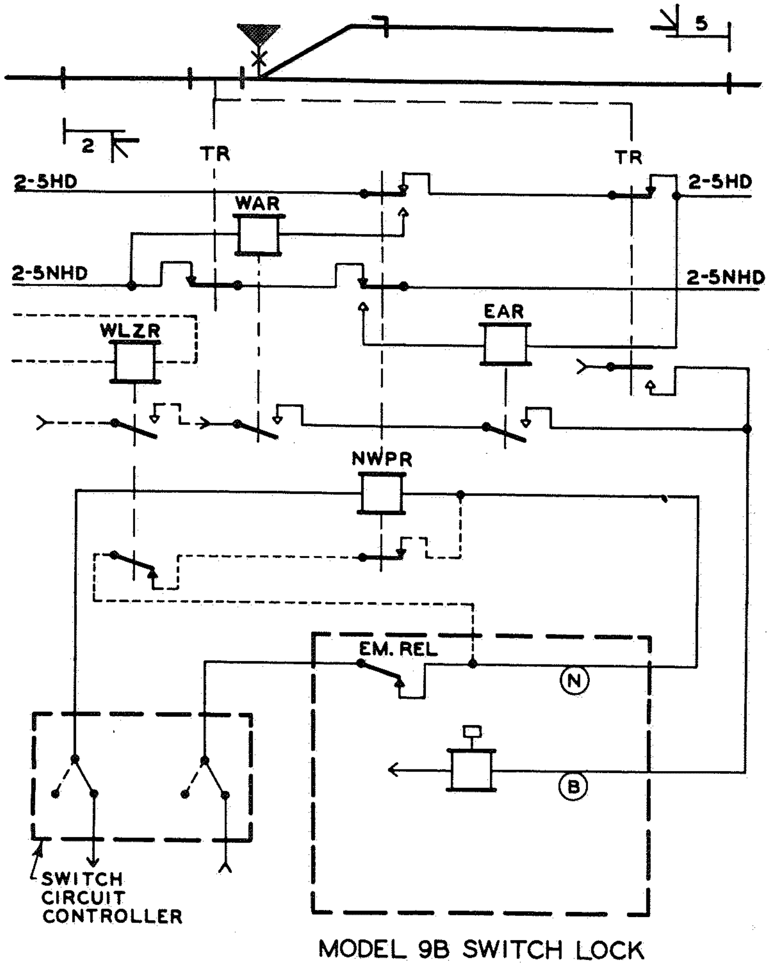

2
5
TR
TR
2-5HD
2-5HD
WAR
2-5NHD
2-5NHD
EAR
WLZR
NWPR
EM. REL
N
B
SWITCH
CIRCUIT
CONTROLLER
MODEL 9B SWITCH LOCK

Figure 526. Typical switch-lock control circuit with emergency release and normally deenergized approach relays. Broken lines show optional supervisory control.

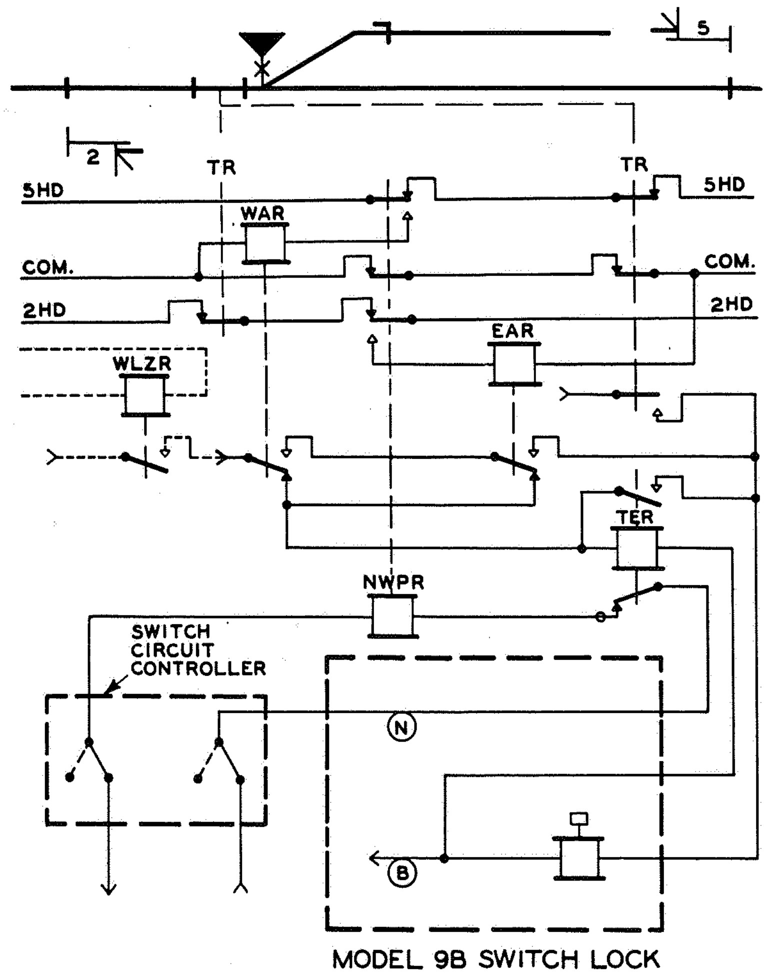
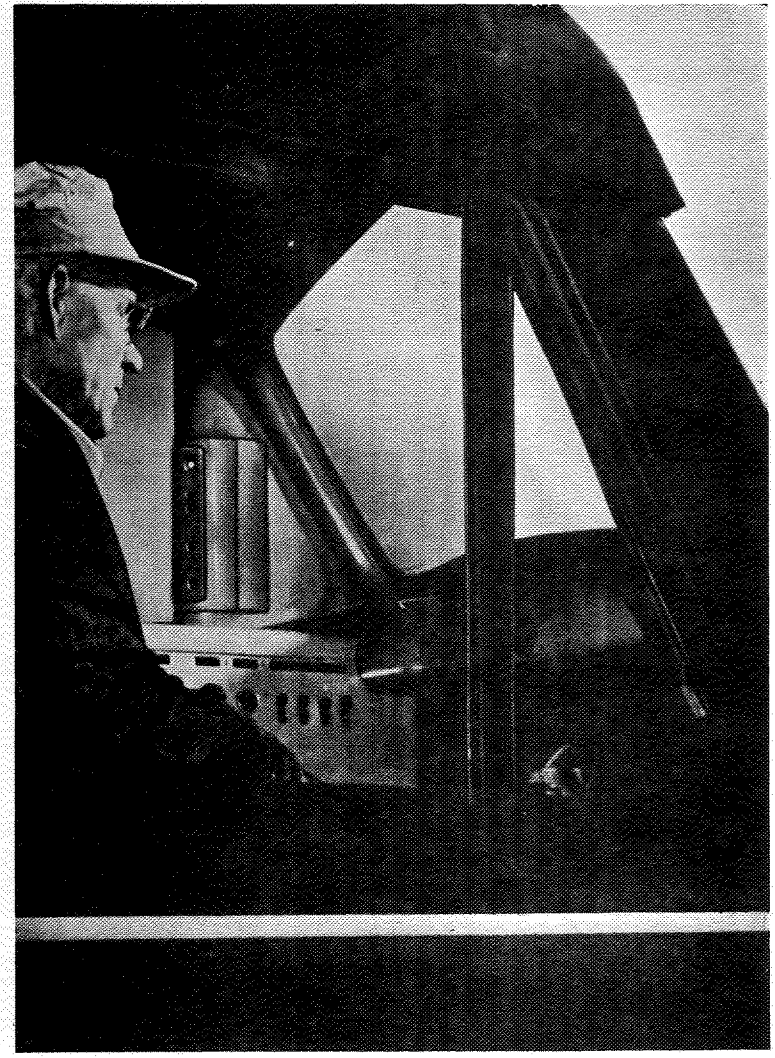


Figure 527. Typical switch-lock control circuit with time release and normally deenergized approach relays. Broken lines show optional supervisory control.

a preliminary movement of the crank handle, contact **N** is opened, breaking the signal control circuits by deenergizing normal switch repeater relay **NWPR**. If no train is approaching, westward and eastward approach relays **WAR** and **EAR** will be energized through back contacts of **NWPR**. With supervisory control, the towerman energizes switch lock control relay **WLZR** by line wire control. Front contacts on **WLZR**, **WAR**, and **EAR** now establish a circuit to the coil of the switch lock. With automatic control, positive battery is fed directly to the heel of **WAR**.

For a movement onto the siding, track relay **TR** is deenergized, its back contact closing a circuit to the lock magnet coil.

Figure 527 shows a typical switch-lock circuit with time release and normally deenergized approach relays. Broken lines show additional circuits for optional supervisory control. The preliminary movement of the crank handle will open the signal controls through contact **N**, dropping **NWPR**. With no train approaching, **WAR** and **EAR** will pick up, closing the lock coil circuit through their front contacts. With supervisory control, **WLZR** must also be energized by a control from the towerman. If a train is approaching, one of the approach relays will not pick up. Thus a circuit through time element relay **TER** and contact **B** on the crank will be completed. When time has run out, a front contact on **TER** will energize the lock coil. Track release for a movement onto the siding is accomplished the same as shown in Figure 526.



CAB SIGNALS

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  Control of Cab Signals 602
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CAB SIGNALS

As we have seen in preceding sections, automatic block systems using wayside signals have been developed to a high degree of perfection, and the signal indications given by such systems can be acted upon with confidence. But on occasion, through no fault of the wayside signal, the engineman cannot see the wayside signal aspect, possibly on account of fog, smoke, or snow. In such cases the engineman must consider the signal as displaying its most restrictive aspect and must control his train accordingly. If this occurs, and the signal is actually not restrictive, time is lost unnecessarily.

Even when visibility is good, if a train enters a block for which the wayside signal is restrictive, the engineman must reduce speed to the maximum permitted for that indication and continue through the entire block at no greater speed. But suppose the block condition responsible for the restriction changes immediately after the train enters the block so that it would be safe to resume normal speed. The engineman, even if he sees the less restrictive wayside signal ahead, cannot take advantage of the improved situation until he actually reaches the wayside signal, since the wayside signal does not apply to the block he is in at the time. He would again lose time by proceeding through the block at a speed lower than necessary.

G-R-S cab signals eliminate such situations by displaying in the locomotive cab, Figure 601, the signal aspect applicable to block and track conditions immediately ahead of the locomotive. Cab signals give a continuous, up-to-the-second indication which is always visible, and which enables the engineman to proceed at maximum permissible speed even when outside visibility is limited. Since the cab signal changes its indication at the same time block conditions change, he is able to increase speed promptly when an indication becomes more favorable, instead of proceeding to the next wayside signal at unnecessarily low speed. Because of these operating advantages, cab signals help to increase average speeds, with resultant improvement in track capacity and on-time performance.

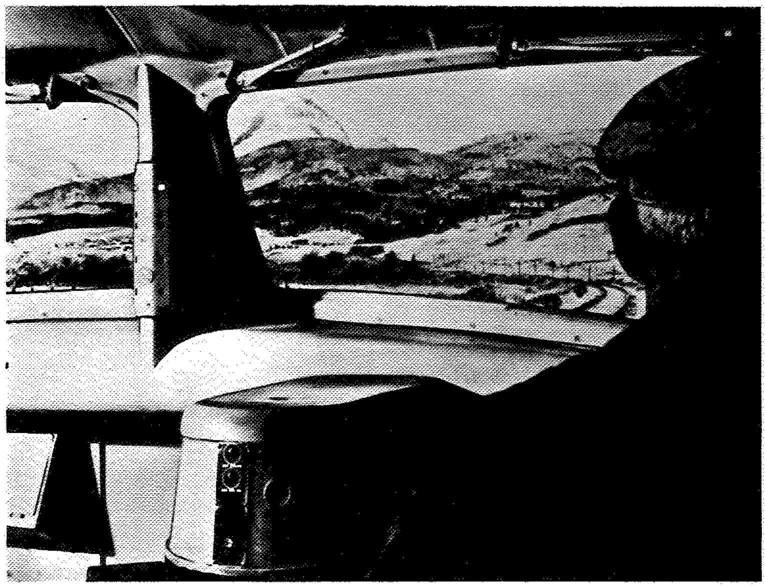
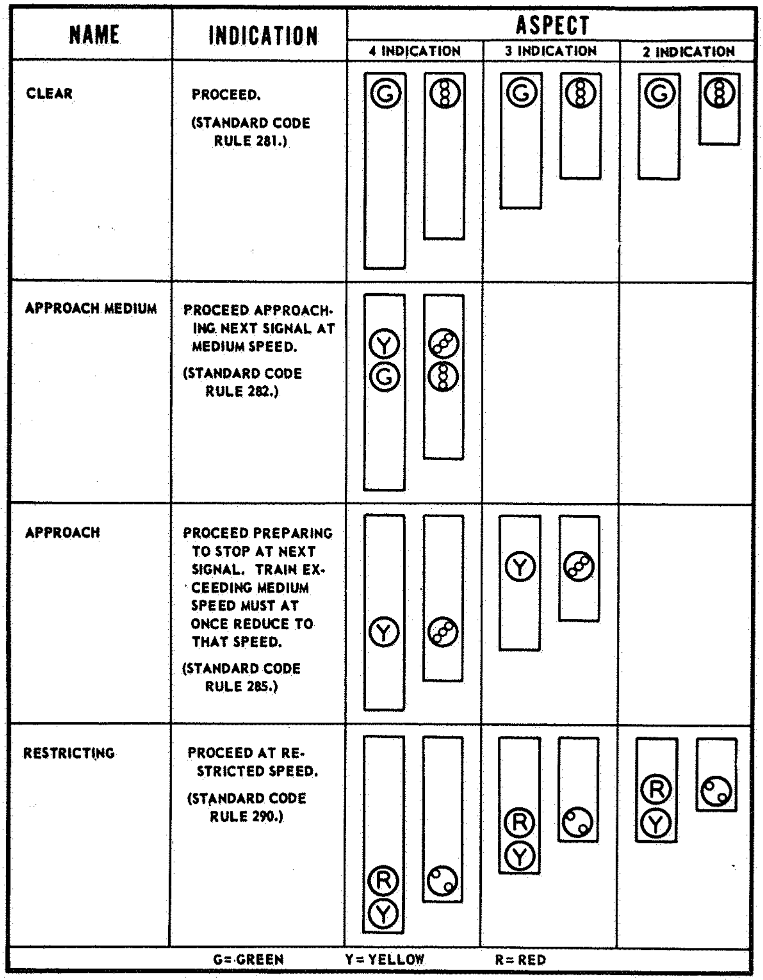


Figure 601. A cab signal aspect is always visible, regardless of atmospheric conditions or physical obstructions.

To enhance the effectiveness of the visual cab signal, a warning whistle is provided which sounds in the cab each time the signal indication becomes more restrictive, and which continues to sound until silenced by operation of an acknowledging contactor.

APPLICATION OF CAB SIGNALS

Cab signals are adaptable to all types of motive power, and can provide the conventional signal aspects. Figure 602 shows the aspects and indications recommended by the AAR.

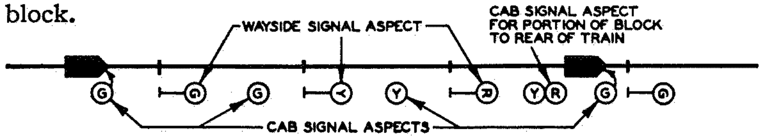


NAME	INDICATION	ASPECT 4 INDICATION		ASPECT 3 INDICATION		ASPECT 2 INDICATION	
CLEAR	PROCEED. (STANDARD CODE RULE 281.)	G		G		G	
APPROACH MEDIUM	PROCEED APPROACHING NEXT SIGNAL AT MEDIUM SPEED. (STANDARD CODE RULE 282.)	Y G					
APPROACH	PROCEED PREPARING TO STOP AT NEXT SIGNAL. TRAIN EXCEEDING MEDIUM SPEED MUST AT ONCE REDUCE TO THAT SPEED. (STANDARD CODE RULE 285.)	Y		Y			
RESTRICTING	PROCEED AT RESTRICTED SPEED. (STANDARD CODE RULE 290.)	R Y		R Y		R Y	

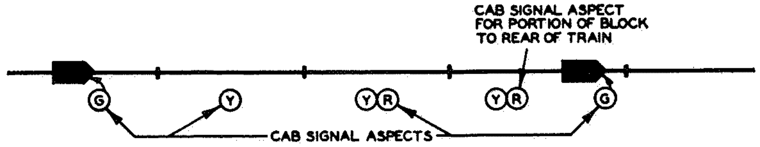
G=GREEN Y=YELLOW R=RED

Figure 602. Cab signal aspects and indications recommended by the AAR.

Cab signals may be used with wayside signals, or they may be used independently in conjunction with speed control. When used with wayside signals, the cab signal aspects (for a three-indication system) for each block in the rear of a train are shown in Figure 603a. If used without wayside signals, an arrangement like that shown in Figure 603b may be used. Note that in the latter the red-over-yellow aspect is carried back a block to the rear of the block occupied by the leading train, to provide the most restrictive cab signal indication before a following train actually enters an occupied block. When wayside signals are used with cab signals, this is not necessary, since the wayside signal shows the entering point of the occupied block.



a. Three-indication cab signal with wayside signals.



b. Three-indication cab signal, no wayside signals.

Figure 603. Signal aspect diagram.

CONTROL OF CAB SIGNALS

The information needed for control of the cab signal is transferred from the track circuit to the locomotive by inductive coupling between the track circuit and circuits on the locomotive. Since inductive coupling is effective only when there is some variation in the track circuit current, steady-energy d-c. track circuits cannot be used.

One means of obtaining a varying current is to use a-c. track circuits, or to superimpose an a-c. component on the d.c. used for wayside signal control. A system in which a.c. is continuously on the track circuit for a clear block, but is not present for a restrictive block, provides two-indication cab signals. Systems of this kind have been used successfully.

If we wish to have more than two indications, we can code the a-c. track current at various rates, such as 75, 120, and 180 times a minute, just as is done with coded track circuits for control of wayside signals. The locomotive is then provided with decoding equipment similar to that used on the wayside, with the cab signal controlled accordingly, to provide three, four, or more indications.

Originally, multiple-indication coded cab signals, like the two-indication uncoded signals, required that the coded track circuit be a.c., or that an a-c. component be superimposed on d-c. coded track circuits. Moreover, the a-c. frequency used was usually a special value, such as 100 cycles, to avoid interference from 60-cycle and 25-cycle foreign currents. In 1951, however, G-R-S introduced an a-c./d-c. coded cab signal system which operates on d-c. as well as on a-c. coded track circuits, and which permits the use of 60-cycle a.c. in the track. The operating principles involved in this are described later in this section.

WAYSIDE CIRCUITS AND EQUIPMENT

For two-indication uncoded cab signals, it is necessary to apply a.c. to the track circuit when the clear signal is desired in the cab, and to remove a.c. at other times. This a.c. may be in addition to d.c. used for wayside signal control. For multiple-indication coded cab signals, the wayside circuits must apply the proper code to the track circuits to obtain the desired indication. If the locomotive cab signal equipment is designed for use with coded a.c., the applied code must be a.c., either alone or superimposed on the d-c. codes used for wayside signals. If the a-c./d-c. cab signal system is used, either a.c. or d.c. may be used in the coded track circuits.

Wayside circuits and equipment suitable for the foregoing types of track circuit operation are described in sections of this handbook dealing with coded track circuits.

LOCOMOTIVE EQUIPMENT AND CIRCUITS

Cab signal equipment on the locomotive operates under conditions which are in many ways more severe than those encountered on the wayside. Equipment is subjected to vibration and shock, and must often be located where it would be exposed to weather, or to the possibility of mechanical damage. Moreover, space is limited on a locomotive, so compactness is essential.

It is necessary, therefore, to provide shock- and vibration-absorbing mountings and to house equipment in sturdy cases which take up a minimum of room and which give reliable protection. A typical mechanism case, installed in a diesel locomotive, is shown in Figure 604. Figure 605 shows the efficient use of space in this case.

Provision must also be made for quick correction of trouble, in order to avoid tieing up the locomotive. This is done by designing the equipment as a group of plug-connected units, any one of which can be quickly replaced, Figure 606.

Organization of Locomotive System

The organization of a typical three-indication cab signal system is shown in Figure 607. For purposes of explanation, it will be assumed that the system is designed for operation with coded a-c. (100-cycle) track circuits in which 180 code rate is used to obtain the clear indication and 75 code rate to obtain the approach indication. Absence of code, resulting from a train shunt or any other reason, produces the restricting indication.

The a-c. code being fed to the track rails is picked up in-

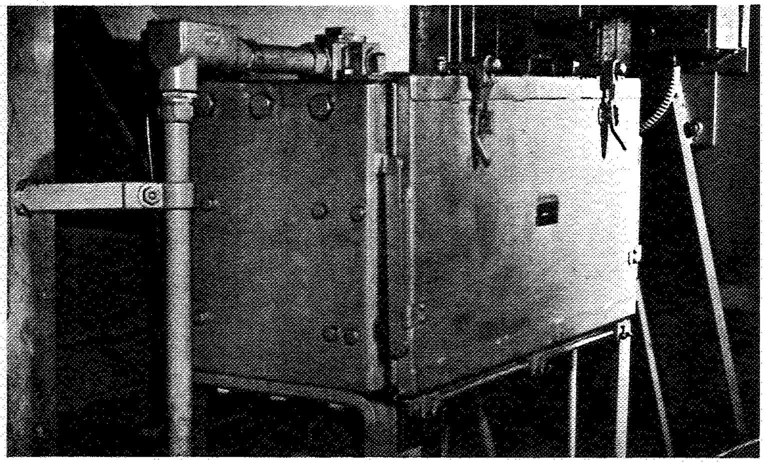


Figure 604. Cab signal mechanism case on diesel locomotive.

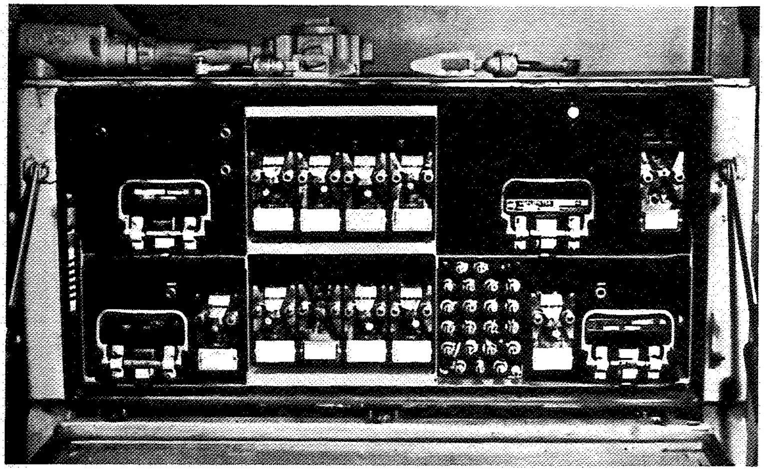


Figure 605. Equipment used with a four-indication cab signal system.

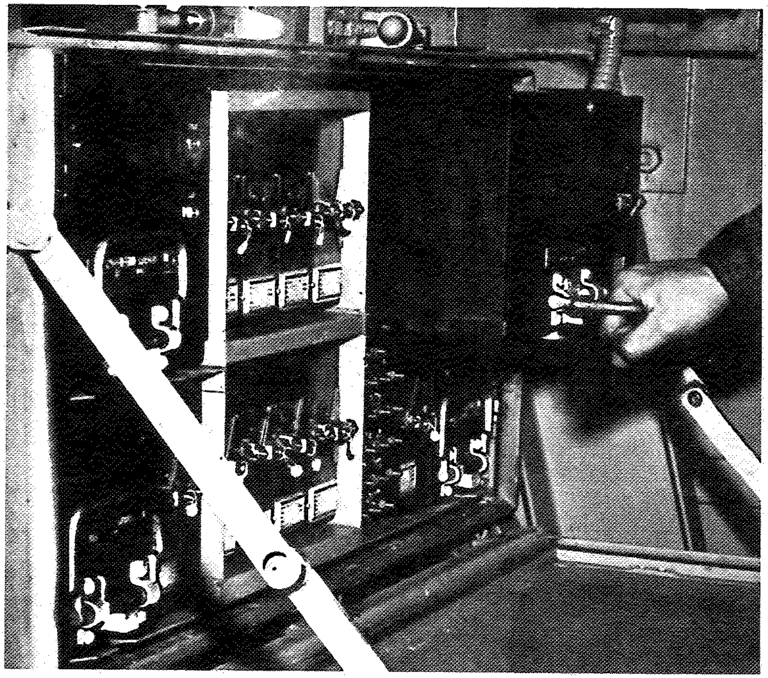


Figure 606. Plug-connected units speed maintenance.

ductively by two receiver coils, one of which is mounted on each side of the locomotive ahead of the leading wheels, directly over the rails, about six inches above rail head. The energy picked up by the receiver coils passes through the amplifilter where frequencies other than 100-cycle are filtered out and the voltage is amplified sufficiently to operate the master relay.

The master relay energizes the decoder unit, the output of which in turn operates relays to produce the clear (green) indication for 180-rate code, and the approach (yellow) indication for 75-rate code. When no code is present, these relays are released, and the restricting (red-over-yellow) indication results.

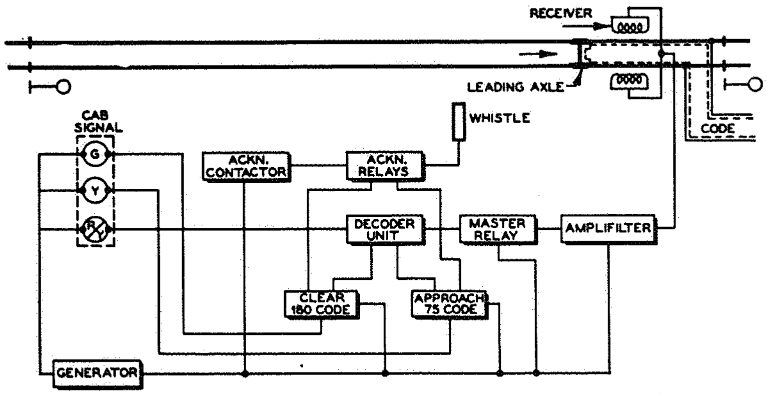

RECEIVER
LEADING AXLE
WHISTLE
CODE
CAB SIGNAL
G
Y
R
ACKN. CONTACTOR
ACKN. RELAYS
DECODER UNIT
MASTER RELAY
AMPLIFILTER
CLEAR 180 CODE
APPROACH 75 CODE
GENERATOR

Figure 607. Organization of three-indication cab signal system.

Associated with the signal control relays are acknowledging relays which cause the whistle to sound each time a signal becomes more restrictive. The whistle is silenced by operation of the acknowledging contactor.

Generator

The generator, in addition to supplying 32-volt d.c. for operation of the signal system, isolates the system from the locomotive electrical supply. On diesel and electric locomotives, the generator is usually part of a motor-generator set driven from the locomotive supply. On steam locomotives, a turbogenerator is used. A typical motor-generator installation is located under the mechanism case in Figures 604 and 606.

Receivers

The receivers consist of coils wound on laminated iron cores. Receivers may be separate units, Figure 608, or two coils may be mounted on a common structure which spans the distance between rails, Figure 609. In both types the coils are sealed in a tough molded rubber casing which provides protection but

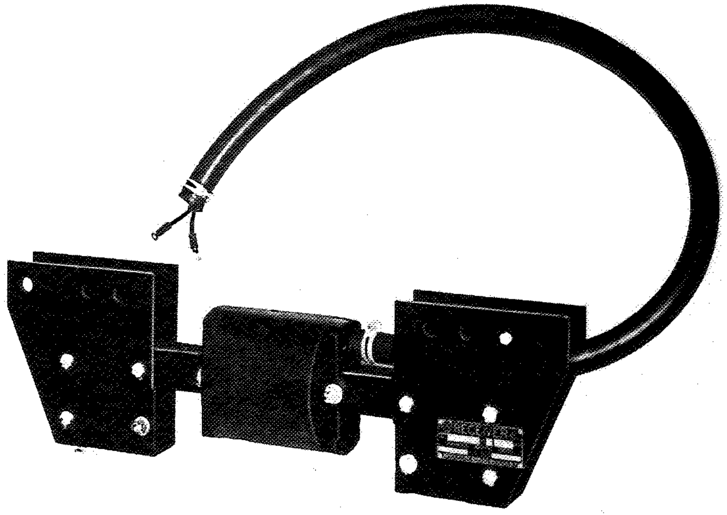


Figure 608. Single receiver.

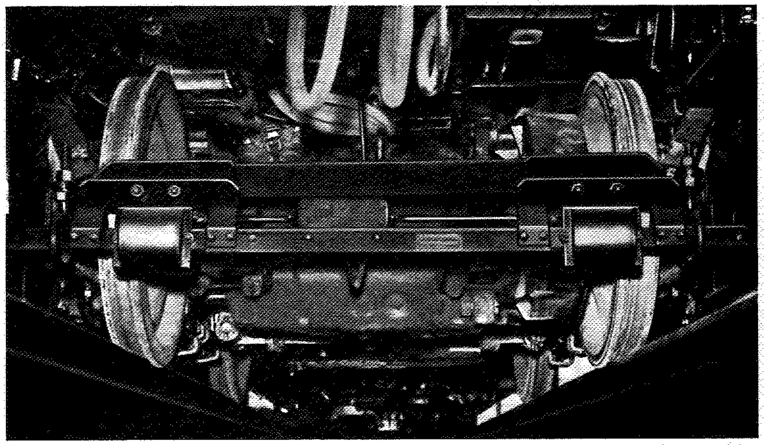


Figure 609. Double receiver installed on multiple-unit type car.

does not interfere with the inductive coupling to the rails. Wire leads from the coils are brought out through a flexible cable or rubber hose.

Receiver Operation

The operating principle of the receiver is shown in Figure 610. In this illustration, the rail section represents the rail portion of the track circuit, energized with a.c. from the transformer. The rail, like any conductor carrying a current, is surrounded by a magnetic flux, indicated by the circles around the rail. The direction of the flux depends upon the direction of the current in the rail. When a.c. flows in the rail, the flux alternates in direction.

The receiver coil and core are within the magnetic field of the rail current, and hence are magnetically excited. When a.c. is in the rail, the receiver excitation alternates, and an alternating voltage is induced in the receiver windings. If the a.c. in the rail is coded, i.e., is turned on and off at some code rate, say 180 times a minute, then the a-c. voltage in the receiver winding goes on and off at the same code rate.

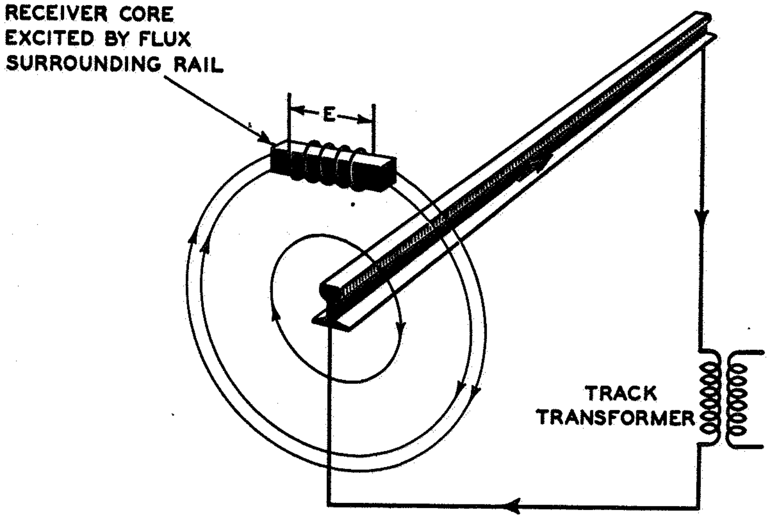


Figure 610. Receiver operation diagram.

Amplifilter

The energy level induced in the receivers is not high enough to operate a code-following relay, so it is necessary to amplify the receiver output. This is done by the amplifilter.

The amplifilter, as its name implies, is a device which filters and amplifies the a-c. input from the receiver. As shown in Figure 611, the receiver output is coupled through transformer T1 to the control grids of a double-pentode vacuum tube. The primary and secondary of transformer T1 are tuned to the a-c. frequency used in the track circuit, thus filtering out frequencies different from 100 cycles. The two pentode sections of the vacuum tube are connected in parallel, and amplify the filtered signal from the receivers. This tube is designed to work at low voltage: the plate and screen circuits are operated directly from the 32-volt supply, and the heater is connected to the same supply through dropping resistor R5.

The a-c. output of the vacuum tube, a greatly amplified replica of the input from the receivers, is applied through transformer T2 to a full-wave rectifier. The rectified output is sufficient to cause relay CR to pick up when a.c. is present in the track circuit. When a.c. is not present in the track, CR releases. When the a.c. in the track circuit is coded, CR follows the code.

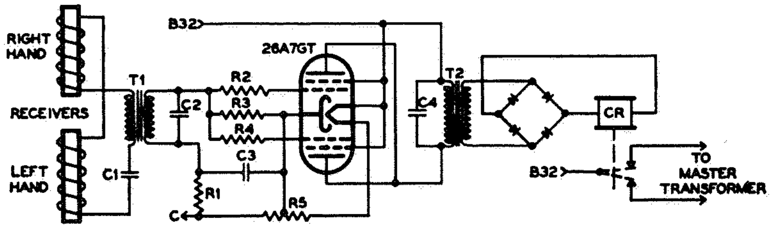


Figure 611. Simplified circuit, amplifilter.

Decoder Unit

The decoder unit includes a master transformer which is excited by the operation of the master relay. Windings on this transformer provide output for control of the "clear" and "approach" relays. The decoder unit used on the locomotive operates in the same way as the decoder used for control of wayside signals by coded track circuits (see section on coded track circuits).

Acknowledging Contactor

The acknowledging contactor, Figure 612, is mounted so that it can be operated conveniently by the engineer. Each time the signal becomes more restrictive, the contactor handle must be depressed and released to silence the whistle. The circuits are arranged so that holding the contactor depressed causes the whistle to sound continuously.

Whistle

The cab whistle, Figure 613, is operated from the locomotive air supply through a solenoid-actuated valve. The valve is arranged so that the whistle sounds when the solenoid is de-energized.

Cab Signal

The cab signal proper, Figure 614, is made up of a housing divided into a number of internal compartments, depending on the signal aspects required. In front of each compartment is a colored roundel (or an appropriate mask, for position-light aspects). In each compartment is a lamp which is lighted as required to produce the desired signal aspect.

The cab signal must be readily visible to both engineer and fireman. In steam locomotives, duplicate signals mounted on each side of the cab have been used. On diesel locomotives, the center-post mounting shown in Figure 614 accomplishes the same result with a single unit.

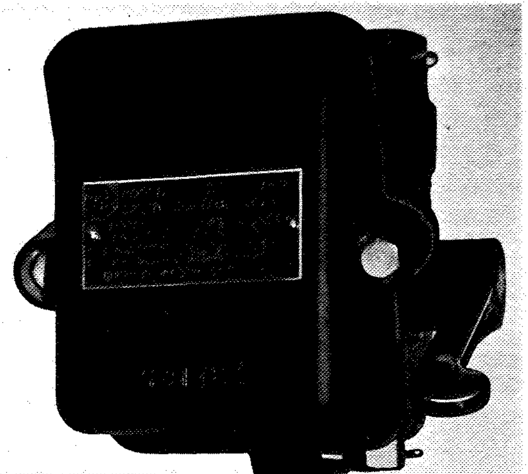


*Figure 612.
Acknowledging
contactor.*

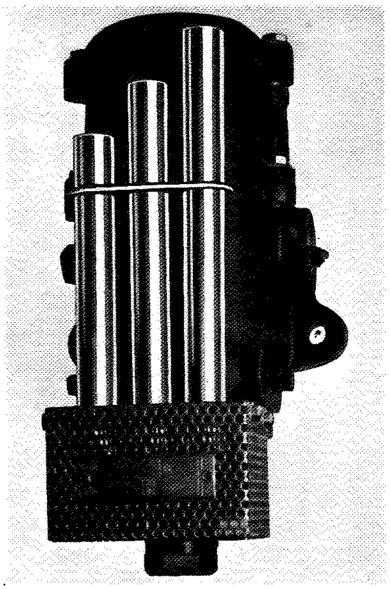


*Figure 613.
Whistle valve.*

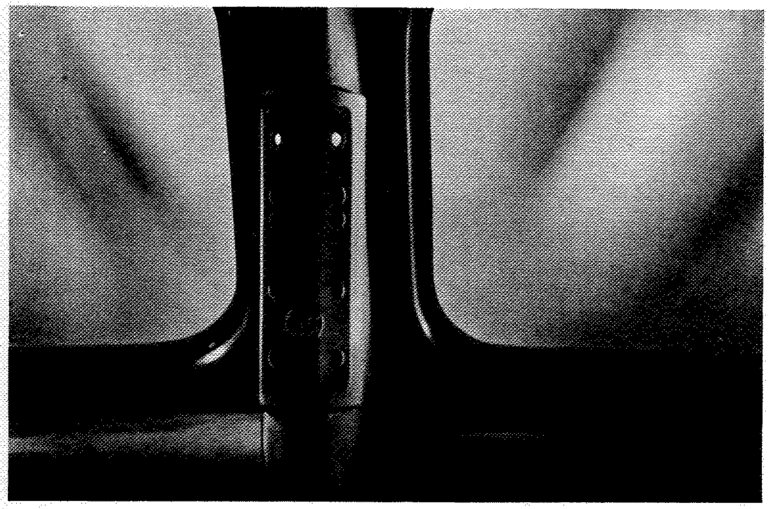


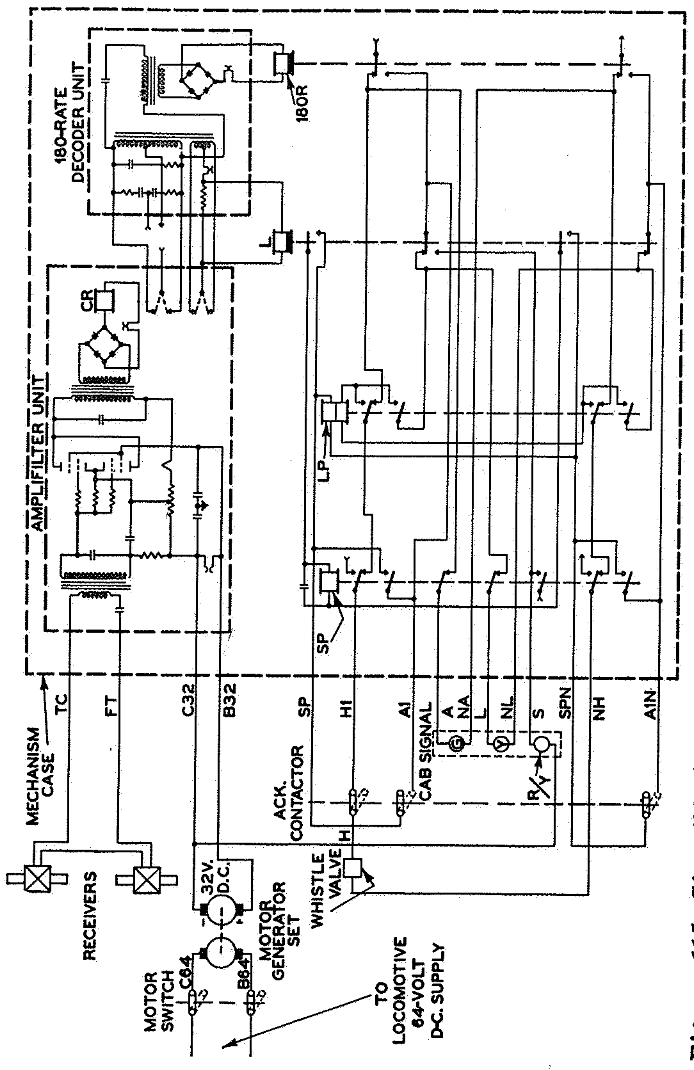
Figure 614. Cab signal installed in center post of diesel cab.

Locomotive Circuits

Figure 615 shows a simplified locomotive circuit for three-indication cab signals. The operation of this circuit from the receivers through relay CR has already been traced. When CR is coding, the master transformer in the 180-rate decoder unit is excited, so that relay L is picked up when 75-rate code is received, and both relay L and relay 180R are picked up when 180-rate code is received. (Section on coded track circuits gives a detailed explanation of how this is done.) If no code is being received both L and 180R are released.

Signal Control Circuits

The portion of the locomotive circuits used for controlling the signal aspects is shown in Figure 616. With 180R up, the green aspect is lighted through front contacts on 180R and a back contact on acknowledging relay SP. With 180R released, and L still up, the condition corresponding to 75-rate code, the



MECHANISM CASE
AMPLIFILTER UNIT
180-RATE DECODER UNIT
CR
RECEIVERS
TC
FT
C32
B32
MOTOR SWITCH
C64
B64
32V. D.C.
MOTOR GENERATOR SET
L
180R
ACK. CONTACTOR
SP
SP
LP
H1
WHISTLE VALVE
H
A1
CAB SIGNAL
A
NA
L
NL
R
Y
S
SPN
NH
A1N
TO LOCOMOTIVE 64-VOLT D-C. SUPPLY

Figure 615. Simplified typical locomotive circuit, three-indication cab signal system. (Relays shown in "clear" position.)

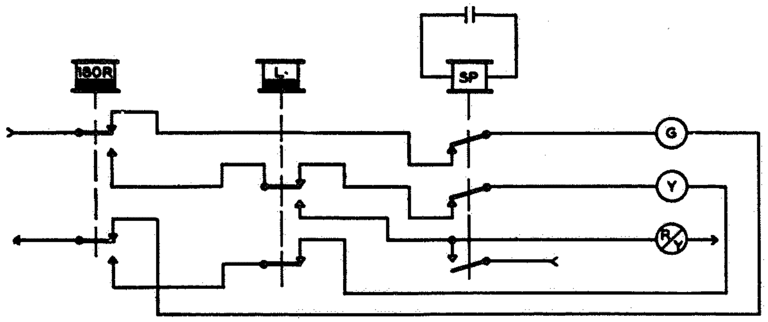


Figure 616. Simplified circuit, signal control.

yellow aspect is lighted through back contacts of 180R, front contacts of L, and a back contact of SP. With both 180R and L down, the red-over-yellow aspect is energized through back contacts of 180R and L. In addition, when the engineman acknowledges the red-over-yellow aspect, SP picks up and sticks up through a back contact of L (not shown in Figure 616). The signal lamp is then also energized through a front contact of SP. SP is made slow release by the condenser shunted around its coils, so the signal cannot change from red-over-yellow to a more favorable aspect until approximately three seconds after the stick circuit through L has been broken. This delays the appearance of a less restrictive indication until a definite code has been established.

Acknowledging Circuits

The portion of the locomotive circuits used for acknowledging is shown in Figure 617. These circuits have been simplified by omitting the duplicate contacts (shown in Figure 615) used to provide double-break control. When the signal is clear, whistle valve WV is energized through a front contact of 180R, and through back contacts of LP and SP. If the signal changes from clear to approach, 180R releases, deenergizing WV, causing the whistle to sound. Operation of the acknowledging contactor energizes LP through a back contact of 180R and a normally-open contact of the acknowledging contactor. When LP comes up, it sticks up on the circuit through 180R back contact, L front contact, and LP front contact. Release of the acknowledging contactor then reenergizes WV through 180R back contact, L front contact, two LP front contacts, SP back contact, and the normally-closed acknowledging contact.

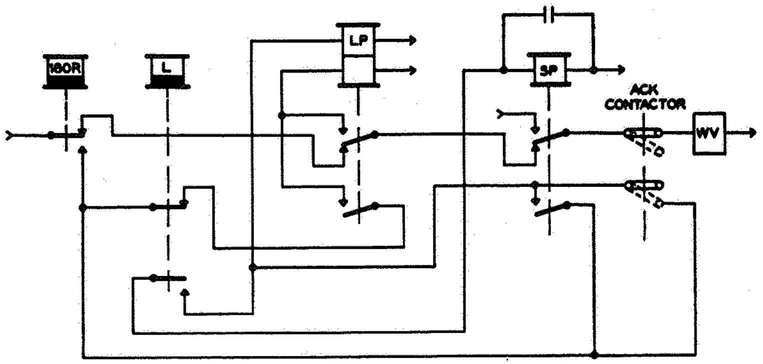


Figure 617. Simplified circuit, acknowledging operation.

If the signal changes from approach to restricting, L releases, opening the stick circuit on LP so that LP also releases. WV is deenergized, and the whistle sounds. Acknowledgment again picks up LP, as in the previous case. In addition, SP also picks up, since it is energized through 180R back contact, the normally-open acknowledging contact, and L back contact. SP sticks up through back contact 180R, its own front contact, and back contact of L. With SP up, LP is held up through 180R back contact, and SP front contact. In addition, WV is reenergized through SP front contact when the acknowledging contactor is released.

When the signal changes back from restricting to approach, L picks up and opens the stick circuit on SP. But SP is slow release, so that SP remains up for a period of about three seconds after L picks up. When SP releases, LP remains up because the stick circuit through L front contact has been reestablished. The whistle gives a momentary "peep" when SP crosses over from its front to back contact, but no acknowledgment is required since WV is energized when SP makes its back contact. If the signal now clears, 180R picks up, and LP drops to reestablish the circuit conditions indicated in Figure 617. As before, a momentary "peep" of the whistle occurs, but acknowledgment is not needed.

A-C./D-C. CAB SIGNALS

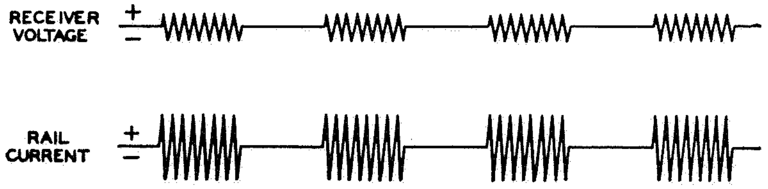
In the preceding section, it was assumed that coded a.c. was used in the track circuits, so that the track-circuit a.c. induced a voltage in the receivers. Suppose now that coded d.c. were used in the track circuit. Each time the code current started up in the rail, the flux linkage around the rail would build up rapidly to some fixed value, and would then remain steady for the remainder of the code pulse. When the track current was cut off at the end of the code pulse, the flux would collapse. As a result, the output of the receivers would not be a succession of a-c. code pulses, but instead, a series of abrupt "spikes" of voltage corresponding to the beginning and end of each d-c. code pulse, with no receiver output in between. The relationship of track current and receiver voltage for both a-c. and d-c. codes is shown in Figure 618.

The amplifilter previously described is not designed to operate with the voltage spikes produced by d-c. code pulses. However, other electronic equipment has been designed which responds to pulses of this kind, and hence permits the operation of cab signals over d-c. coded track. This equipment detects the transient effects associated with the beginning and end of code pulses, so it can be used not only with d-c. coded track, but also with a-c. coded track, because a-c. code pulses, too, produce transient effects. Moreover, since the transients are not a matter of the specific a-c. frequency used in the track circuit, the a-c./d-c. cab signal system can use coded 60-cycle current in the track circuits, with satisfactory performance even when there is foreign 60-cycle current in the track of greater magnitude than the code current.

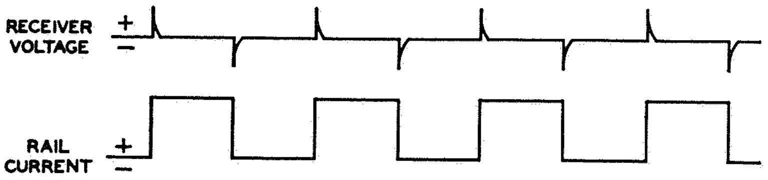
Either of two methods of decoding may be used with the a-c./d-c. cab signal system. One of these is similar to the system previously described, with the output of the electronic equipment driving a code-following master relay, with decoder units, relays, etc. The second method utilizes a vacuum-tube unit which determines the code rate electronically and operates signal control relays in accordance with the code rate received.

TRANSISTORS USED IN CAB SIGNALING

Recently, cab signal amplifilters have been placed in service in which transistors are used as amplifiers instead of a vacuum tube. At the time of writing, this equipment is still in an experi-



a. Coded a-c. track circuit.



b. Coded d-c. track circuit.

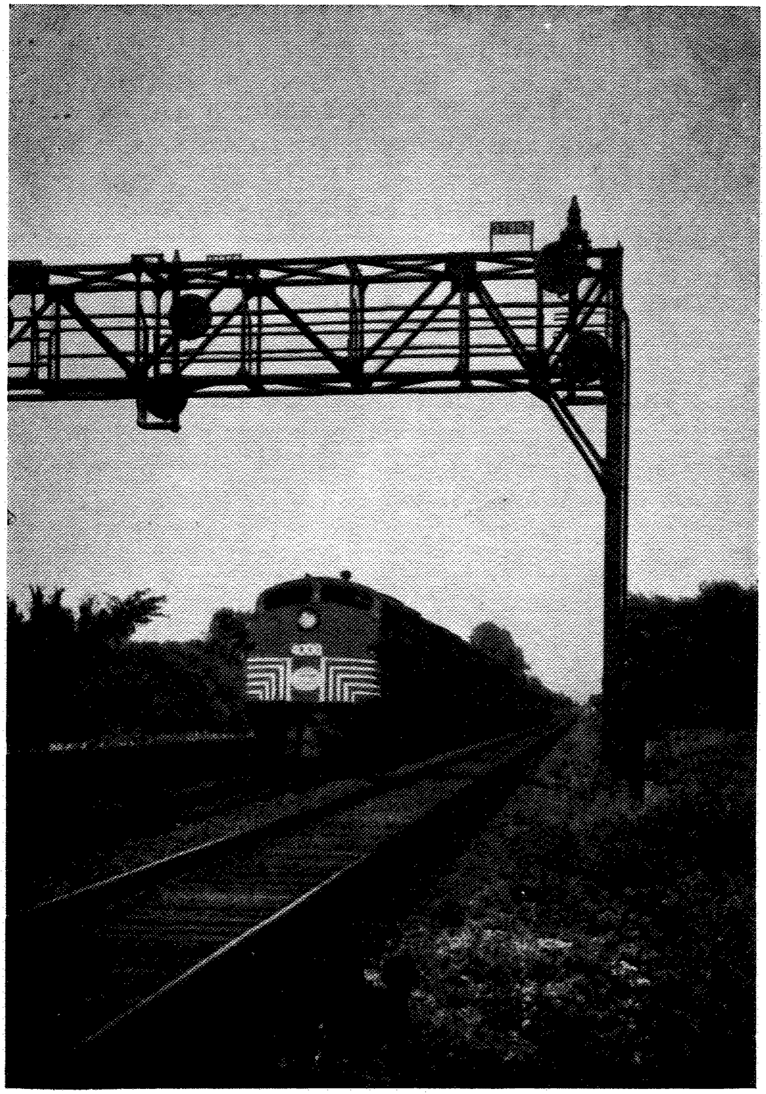
Figure 618. Receiver response to a-c. and d-c. track code.

mental stage of development. Preliminary results indicate that transistors, with their small size, lower power requirements, resistance to the effects of shock and vibration, and potentially long life, may eventually displace the vacuum tube in cab signal systems.

CONTINUOUS TRAIN CONTROL

A cab signal system provides information on block conditions directly on the locomotive. By combining a speed governor and brake-applying apparatus with the cab signal system, we can automatically regulate train speed so that it does not exceed limits appropriate to the signal indication. We can also enforce penalty stops if the engineman fails to perform certain actions, such as operating the acknowledging contactor as required.

The following section of this handbook describes such continuous train control systems.



TRAIN CONTROL

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TRAIN CONTROL SYSTEMS

Train control systems may be divided into two general kinds: intermittent and continuous. Intermittent systems transmit control information between the wayside and the locomotive only at fixed points along the roadway, usually in the vicinity of the wayside signals. Continuous systems transmit control information between the wayside and locomotive throughout each block.

Intermittent systems are usually of the train-stop type; i.e., unless the engineman observes the requirements of the system, the penalty is a train stop. Continuous systems are usually of the speed-control type, in which the system automatically enforces maximum speed limits consistent with block conditions. However, continuous systems, too, enforce a complete train stop if certain operating requirements are not fulfilled.

TRIP STOPS

The trip stop, as it is customarily used, is an absolute system which automatically stops any train attempting to pass a stop signal. This system operates by mechanical contact between a wayside trip arm and a brake trip switch on the train. When the signal is clear, the wayside trip arm is lowered so that trains may pass at will. When the signal is at stop, the arm is raised and mechanically engages the brake trip switch on any train attempting to pass the signal.

OPERATION

Several forms of trip stop have been used, operated either electrically or electro-pneumatically. One type manufactured by G-R-S is shown in Figure 701. This consists of an induction motor of comparatively low speed, a train of gears, and a circuit controller, all housed in a cast iron case. The main shaft of the mechanism extends through suitable bearings in the case to the shaft extension, on which the trip arm is mounted.

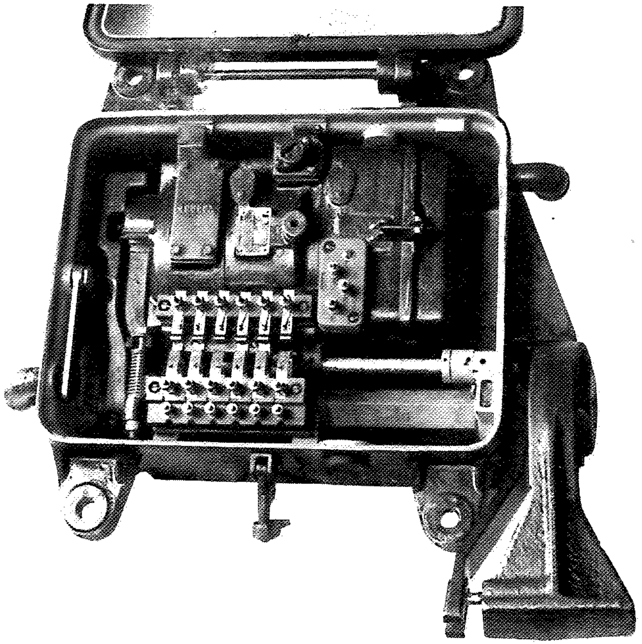


Figure 701. Trip stop, cover open.

Trip arms are operated up to tripping position by a heavy coil spring and are driven down by the motor. After drive-down is complete, an electromagnetic device holds the stop in clear position. The arrangement of spring, drive-down motor, and electromagnetic holding device provides fail-safe operation, since the trip stop automatically goes to the stop position in case of interruption of the energy supply.

Trip arms are adjusted so that the arm rises to a point approximately 2½ inches above the top of the running rails when in stop position, and lowers to approximately 1 inch below the top of the rails when cleared. Operating time is approximately two seconds.

For flexibility of train operation, release contactors may be provided at interlocking home signals so that when the call-on signal is clear the trip arm may also be cleared, even though the interlocking signal is itself at stop.

APPLICATION OF TRIP STOPS

The trip stop, because of its mechanical nature, has certain limitations in application. Severe snow and ice conditions, for example, may interfere with proper operation of the wayside arm. Moreover, the train trip switch may be tripped by wayside obstructions. As a result, the trip stop has found its widest use in the signal systems of the rapid transit subways, such as those of New York City. In such applications there is substantial protection from weather and wayside obstructions, and the trip stop provides a simple, dependable means of enforcing compliance with stop signals. A typical subway installation, with a G-R-S mechanism mounted between the rails, is shown in Figure 702.

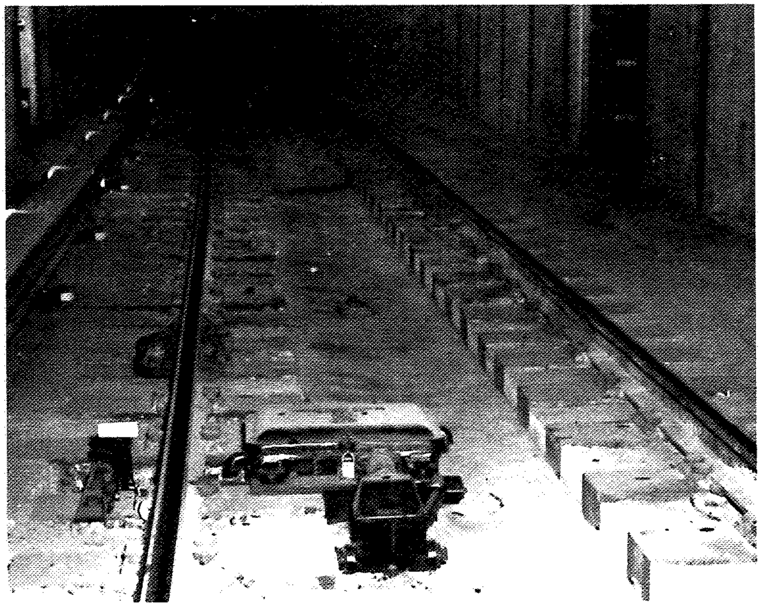


Figure 702. Trip stop (trip arm raised) installed between subway rails.

INTERMITTENT INDUCTIVE TRAIN CONTROL

The intermittent inductive system of train control is the most widely applied of all train control systems. This is a permissive system which allows a train to pass a restrictive signal without penalty provided that the engineman operates an acknowledging contactor when passing the wayside element.

Transmission of control between the wayside and the moving locomotive is accomplished without mechanical contact between the wayside element and locomotive element. A single relay contact controls the clear and restrictive condition of the wayside element, and no energy is required in this control circuit. Transmission of control is effective at all operating speeds.

OBJECT OF SYSTEM

The object of the G-R-S intermittent inductive train control system is to enforce observance of the speed-restricting indications of wayside signals by requiring the engineman to "acknowledge," i.e., to operate a contactor, when passing signals displaying such indications. "Speed-restricting indications" include all indications other than "proceed."

PENALTY FOR FAILURE TO ACKNOWLEDGE

The penalty for failure to acknowledge a speed-restricting indication is an automatic brake application which cannot be released until one of the following conditions has been met, depending upon the type of installation:

a. The engineman leaves his accustomed operating position and operates a reset contactor located at some other point on the locomotive.

b. A predetermined time interval has elapsed after the engineman has operated a reset contactor located convenient to his accustomed operating position.

c. Train speed has been reduced to a predetermined low value and the acknowledging contactor operated.

The effect in all cases is the same: the train is stopped before the brakes can be fully released.

TRANSMISSION OF CONTROL

Transmission of control between the wayside signal circuits and the locomotive is accomplished through the interaction of two devices, one mounted beside the track, called the inductor, Figure 703, and one carried on the locomotive, called the receiver, Figure 704.

The inductor has a U-shaped core of laminated electrical sheet steel fitted with pole pieces. It is usually equipped with a winding for control purposes, but this may be omitted. The inductor is located on the ties, parallel with and outside the gauge line, and with its pole faces 2½ inches above the top of rail.

The receiver is an electromagnet, with a laminated core of inverted U-shape. The receiver carries two windings and has pole pieces of the same spacing as those of the inductor. The receiver is mounted on one of the locomotive journal boxes by means of suitable brackets. It is adjusted so that as the locomotive moves along the track the receiver passes vertically above each inductor, with about 1½-inch clearance between their respective pole faces.

The method of transmitting control from the wayside to the

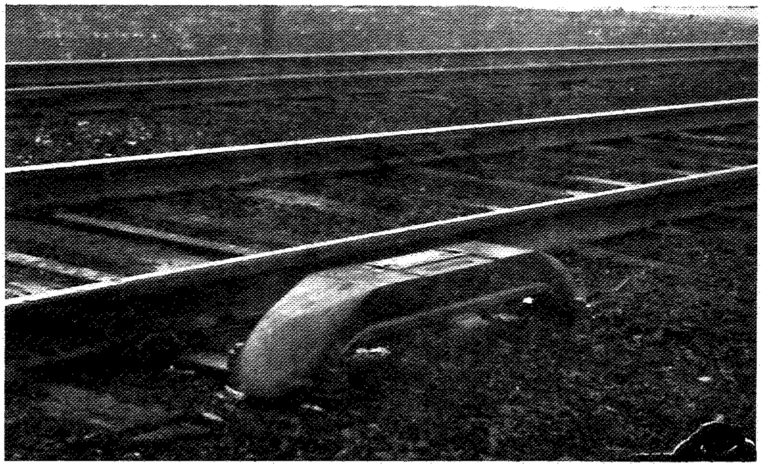


Figure 703. Inductor.

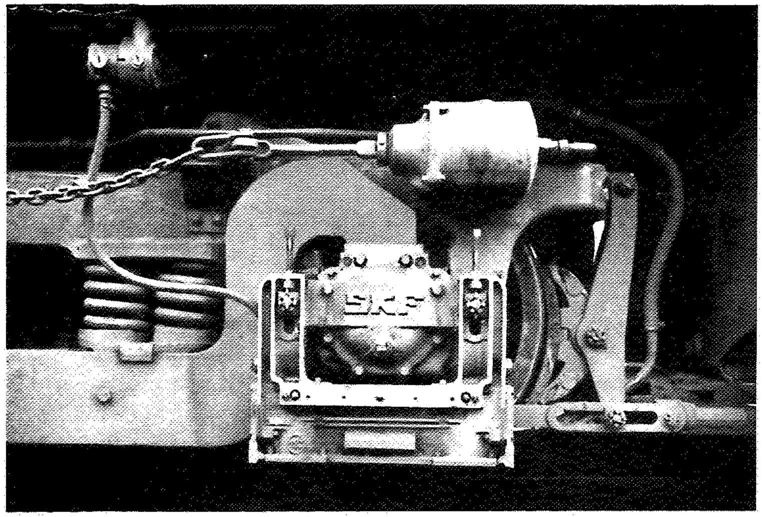


Figure 704. Receiver on journal box of general purpose diesel.

moving locomotive is shown in simplified form in Figure 705. The circuits on the locomotive are controlled through normally-energized primary relay R1; if R1 is deenergized, an automatic brake application occurs unless the acknowledging contactor (not shown) is in its actuated position. R1 is energized through its own front contact and the secondary coil wound on the receiver core structure.

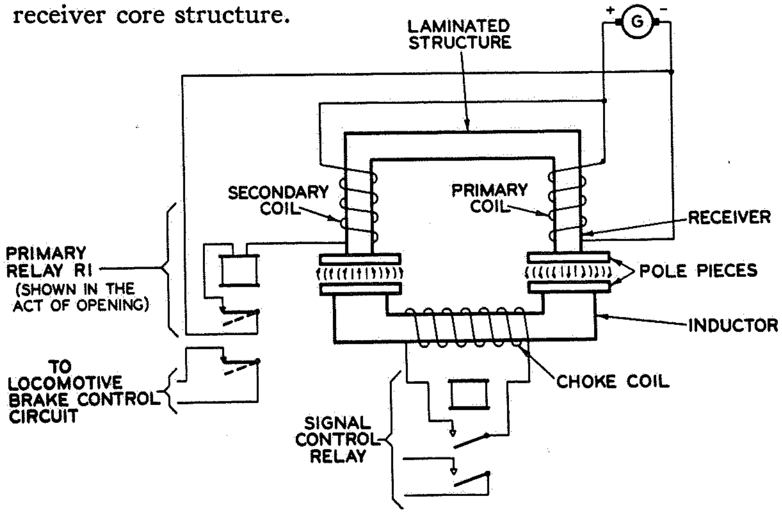


Figure 705. Principle of intermittent inductive control, wayside to train.

Also wound on the receiver core structure is a primary coil which is continuously energized from the generator. The current flowing through the primary coil magnetizes the receiver core structure, but the strength of the magnetic flux is limited when the receiver is not over an inductor by the long air gap between the pole pieces. As the locomotive moves along the track between inductors, the magnetic and electrical conditions in the receiver remain unchanged, and R1 is held energized.

During the interval in which the receiver passes over an inductor, conditions affecting the magnetic flux in the receiver change rapidly. At this time the inductor provides a good magnetic path between the pole pieces of the receiver with relatively small air gaps at each pole. As a result, a surge of magnetic flux builds up in the receiver, inducing a voltage in the secondary coil which bucks the voltage from the motor-generator set.

Curve A-B-C-D-E in Figure 706 shows the effect this induced voltage would have on the current passing through R1 if R1 were not a stick relay. Starting with the normal current at point A, the bucking voltage causes the relay current to drop to a minimum at D. Then, as the receiver moves away from the inductor, the current rises again to its normal value. (The small fluctuations on the current curve before and after the main current dip are caused by minor flux variations as the receiver approaches and leaves the inductor, and have no effect on the over-all operation of the system.)

In actual practice, of course, this complete curve would not occur, because relay R1 would drop as soon as the current became less than the dropaway current shown in Figure 706 and would then remain down because of the opening of the stick circuit.

Since the system must distinguish between restrictive and non-restrictive conditions, provision is made for controlling the effect of the inductor on the receiver in accordance with signal indications. This is done by the choke coil (sometimes called "control" coil) wound on the inductor core, as shown in Figure 705. When the signal is restrictive, the signal control relay is down, leaving the choke coil open-circuited. Under this condition no current can flow in the coil, and the inductor produces a flux surge in the receiver to drop R1, as we have already seen. But if the signal is clear, the signal control relay is up, and the choke-coil circuit is closed through a front con-

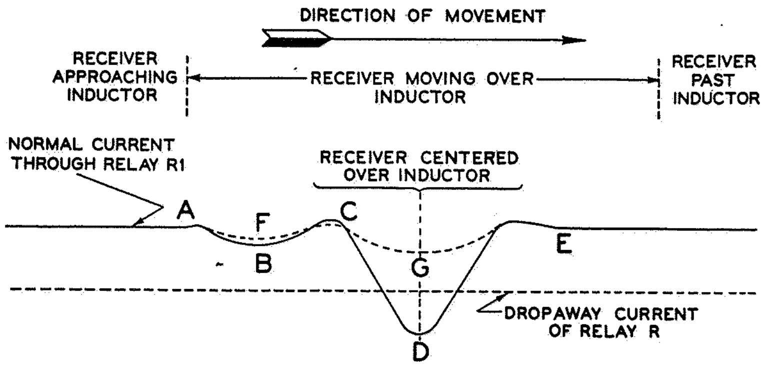


Figure 706. Current through relay R1.

tact on the signal control relay. Now when the receiver passes over the inductor, and the flux starts to build up in the receiver-inductor magnetic circuit, the voltage induced in the choke coil causes current to flow through the coil. According to the laws of induced currents, the magnetic flux produced by this current opposes the magnetic flux which causes the current. As a result, the net change in flux is much less than the change which occurs when the choke coil is open-circuited, and the bucking voltage which appears in the secondary coil is much smaller. Curve **A-F-C-G-E** in Figure 706 shows the current variation in relay R1 under these conditions. The current does not go below the dropaway value at any point, so that R1 remains energized while the receiver passes over the inductor.

To summarize: when the signal is restrictive, the inductor choke-coil circuit is open, and the inductor produces a flux change in the receiver which causes R1 to drop. When the signal is clear, the inductor choke-coil circuit is closed, and the flux change produced in the receiver is not enough to drop R1.

Note that the transmission of control between inductor and receiver requires no energy in the inductor winding. Whether or not a locomotive receives a train control pulse depends only on the inductor choke-coil circuit. If this circuit is open, primary relay R1 drops when the receiver passes; if the circuit is closed, R1 remains energized. At locations where it may be desirable to require acknowledgment at all times, an unwound inductor can be used. Such an inductor has no choke coil to suppress the flux build-up, and so always produces a train control pulse in passing receivers.

Since acknowledgment proves that the engineman is alert, the system permits him to retain full control of the brakes when a restrictive inductor is passed while acknowledgment is being made. This is done by circuits through the acknowledging contactor which prevent a brake application when R1 drops, and which also provide for reenergizing R1 after it is down. To avoid the chance that the acknowledging contactor might be continuously held in the actuated position, making the train control system ineffective, a timing mechanism is included in the contactor. This produces an automatic brake application if the contactor is held closed for more than 15 seconds.

WAYSIDE EQUIPMENT AND CIRCUITS

The basic equipment required on the wayside for the intermittent train control system is the inductor itself, a relay contact which is closed when the signal indicates proceed and is open at all other times, and the necessary wires for connecting the inductor to the relay contact.

In cases where a permanent restriction is required, the only wayside equipment needed is an unwound inductor.

Inductor Mounting and Location

The inductor is usually mounted on first-quality sawed ties 9 or 9½ feet long. A wide variety of mounting arrangements are used by different railroads, all designed to maintain permanent alignment of the inductor with respect to the running rail.

The inductor is placed sufficiently far in the rear of the insulated joints at a signal so that it will act upon a receiver before the leading wheels of the locomotive pass the first insulated joint. This distance depends on the length of locomotives operated, but is generally between 60 and 75 feet.

Inductor Control Circuit

Figure 707 shows a simplified circuit illustrating the principle of inductor control. Note that the inductor control circuit is taken through a front contact of the D relay. This means that the inductor is in its non-restrictive condition only when the D relay is picked up, i.e., the signal is green. The engineman must therefore acknowledge all signals other than green if he wishes to pass the inductor without receiving a penalty train stop.

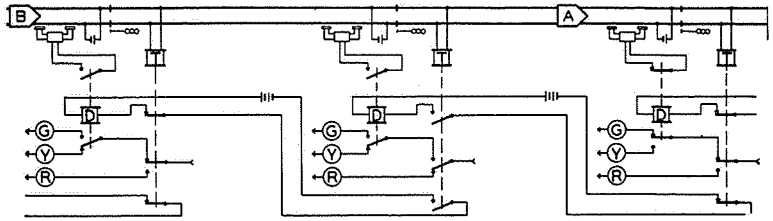

B
A
D
D
D
G
Y
R
G
Y
R
G
Y
R

Figure 707. Typical circuit, inductor control.

LOCOMOTIVE EQUIPMENT

In addition to the receiver, a typical locomotive is equipped with the following train control apparatus:

a. Electro-pneumatic valve
b. Cut-out cock
c. Acknowledging contactor
d. Acknowledging whistle
e. Reset contactor
f. Mechanism
g. Motor-generator
h. Miscellaneous wiring and air piping

A typical arrangement of the above equipment is shown in Figure 708.

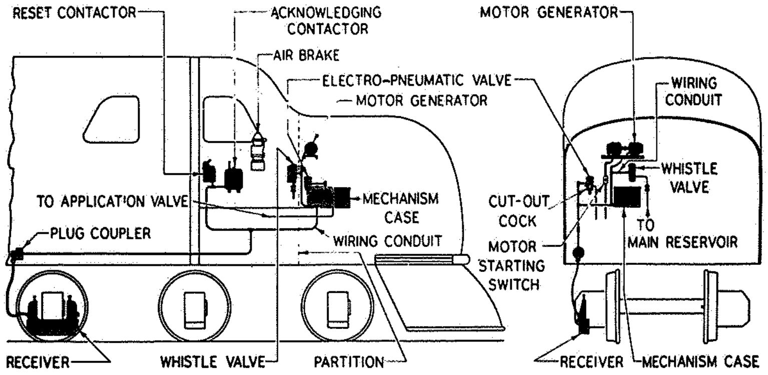

RESET CONTACTOR
ACKNOWLEDGING CONTACTOR
AIR BRAKE
ELECTRO-PNEUMATIC VALVE
MOTOR GENERATOR
MOTOR GENERATOR
WIRING CONDUIT
WHISTLE VALVE
TO MAIN RESERVOIR
TO APPLICATION VALVE
PLUG COUPLER
MECHANISM CASE
WIRING CONDUIT
CUT-OUT COCK
MOTOR STARTING SWITCH
RECEIVER
WHISTLE VALVE
PARTITION
RECEIVER
MECHANISM CASE

Figure 708. Typical arrangement of intermittent inductive train control apparatus on locomotive.

Electro-Pneumatic Valve

The electro-pneumatic valve, Figure 709, is a solenoid-operated air valve which is normally held energized. This valve is controlled through the train control circuits so that passing a restrictive inductor causes the electro-pneumatic valve to become deenergized unless the acknowledging contactor is actuated at the time. When the electro-pneumatic valve is deenergized, it opens a control air line which causes the brake application valve (part of the air brake system) to initiate a service brake application. If such an application occurs, the engineman may, if desired, increase the application to emergency by his brake valve. He cannot, however, obtain release until the electro-pneumatic valve is reenergized.

Cut-Out Cock

The cut-out cock is used to cut the electro-pneumatic valve out of service in case of trouble in the train control equipment.

Acknowledging Contactor

The acknowledging contactor, Figure 710, is mounted in the locomotive cab in a position convenient to the engineman. By

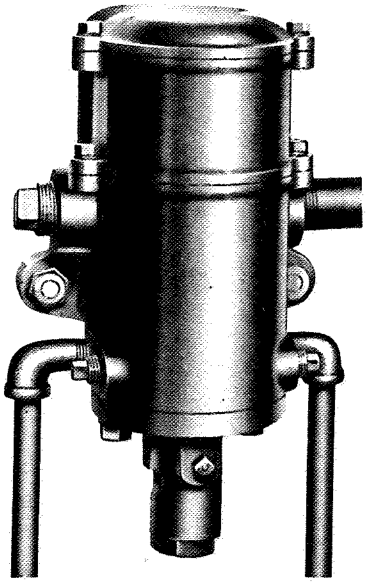


Figure 709.
Electro-pneumatic valve.

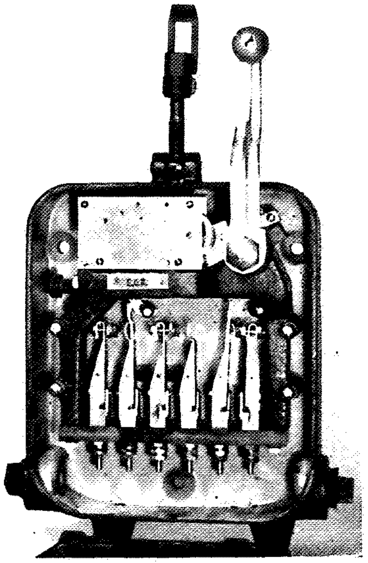


Figure 710.
Acknowledging contactor, cover open.

closing this contactor just before the locomotive passes a restrictive inductor, the engineman averts an automatic brake application.

Acknowledging Whistle

The acknowledging whistle, Figure 711, is mounted in the cab, and sounds momentarily each time a restrictive inductor is passed while proper acknowledgment is made. Quieting of the whistle indicates that the train control circuits have returned to normal condition, and that the acknowledging contactor may be released. The sounding of the acknowledging

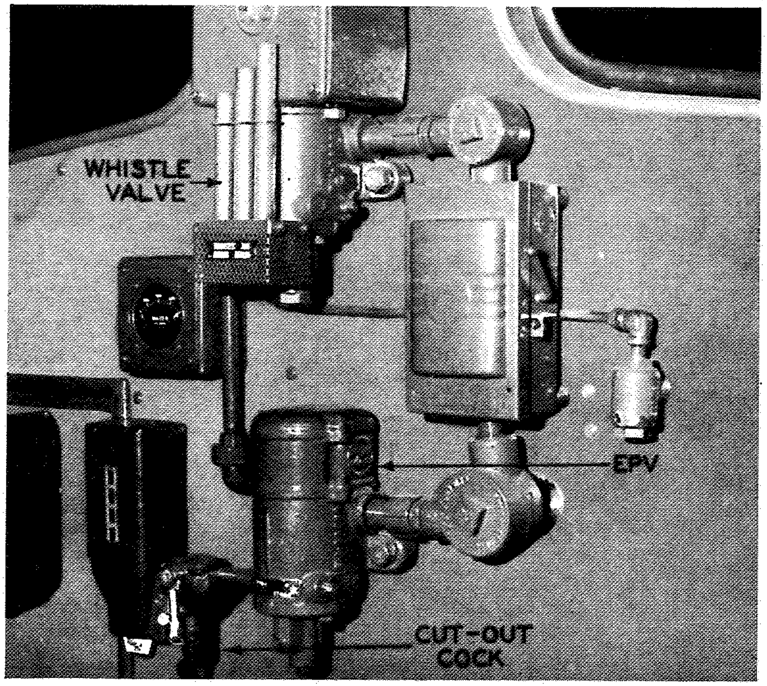


Figure 711. Acknowledging whistle valve, electro-pneumatic valve, and cut-out cock in cab of general-purpose diesel.

whistle shows that the train control equipment is responding properly to the restrictive condition.

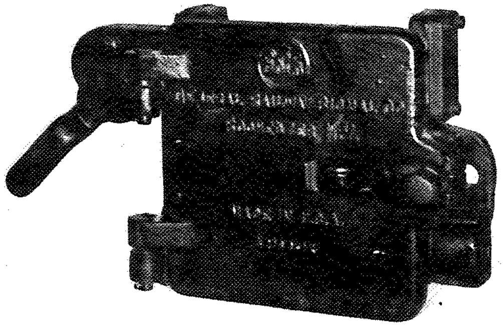


Figure 712.
Reset contactor,
time-delay type.

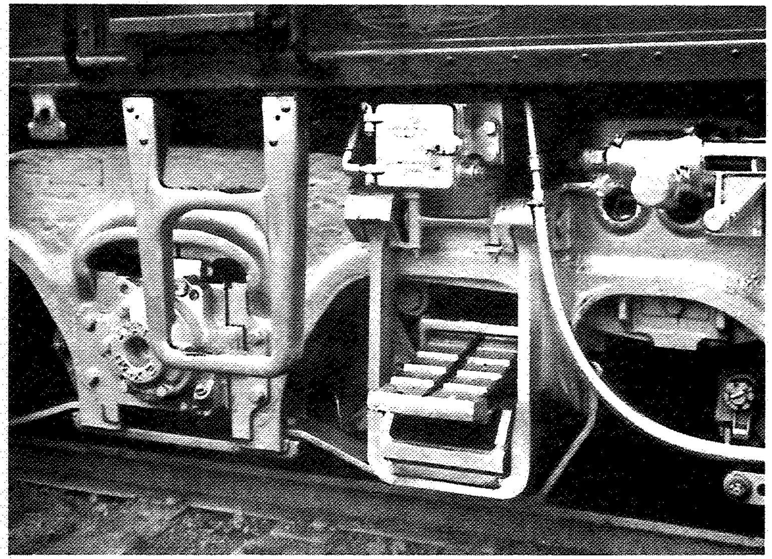


Figure 713. Reset contactor mounted outside locomotive, adjacent to cab steps.

Reset Contactor

The reset contactor is used for resetting the train control circuits to permit brake release after an automatic brake application has occurred. One type of reset contactor, Figure 712, is mounted convenient to the engineman, but is equipped with a timing mechanism which prevents reset until after a specified interval has elapsed from the time the reset handle is operated. Another type, Figure 713, omits the time-delay feature, but is located so that the engineman cannot reach it without leaving his operating position. In either case, the effect is to prevent brake release until the train has been stopped. In some cases a speed governor is used on the locomotive, and the reset contactor is omitted. The reset circuits are then controlled through the acknowledging contactor and a low-speed contact on the governor. Again the effect is to prevent brake release until the train has been stopped.

Mechanism

The mechanism, Figure 714, consists of the relays, ballast resistors, and related items associated with the train control circuits. This equipment is shock-mounted in a mechanism case, which may be carried in the nose of road type diesel-electric locomotives, or on the running board of general-purpose diesel-electric locomotives.

Motor-Generator Set

The motor-generator set operates from the locomotive d-c. supply and delivers the 32-volt d-c. energy required by the train control system. The motor-generator set also serves to isolate the train control system from the locomotive wiring.

Miscellaneous

In addition to the foregoing major items, the locomotive train control equipment includes wiring, conduit and rubber hose (for wires), plug couplers for electrical connections, and piping for air system connections.

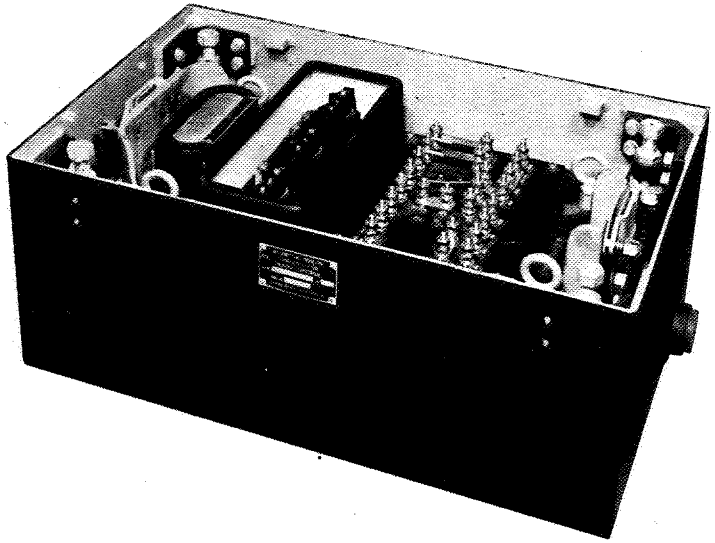


Figure 714. Mechanism case, cover off, showing mechanism on shock mount.

LOCOMOTIVE CIRCUITS

Figure 715 shows, in simplified form, the basic circuit used on a locomotive equipped with intermittent inductive train control effective for forward running. This circuit is drawn for the normal condition, i.e., as it is with the train proceeding between inductors with the brakes under full control of the engineman.

Relays R1, R2 and R3 are actually special units with rotary armatures, but are drawn as conventional relays in Figure 715 for the sake of clearness.

In Figure 715, junction P2 is normally energized from B32 through front contacts of R2 and R3. From junction P2 current flows through the following circuits to C:

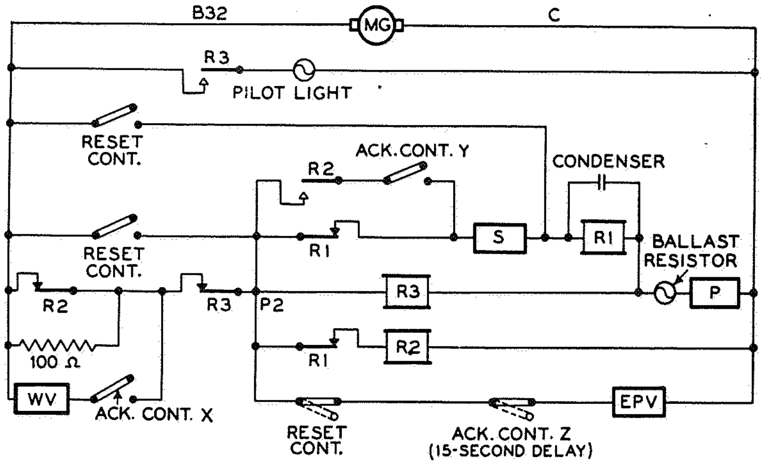


Figure 715. Simplified locomotive circuit, intermittent inductive train control.

a. Through a normally-closed reset contact, normally-closed acknowledging contact Z, and the electro-pneumatic valve EPV, energizing EPV.
b. Through a front contact of R1 and the coil of R2, energizing R2.
c. Through the coil of R3, the current-stabilizing ballast resistor, and receiver primary winding P, energizing R3 and P.
d. Through a front contact of R1, receiver secondary winding S, the coil of R1, the ballast resistor, and P, energizing S and R1.

When the receiver passes over a restrictive inductor, the bucking voltage induced in S causes R1 to release. When R1 releases, the coil of R2 is deenergized by the opening of the R1 front contact, and R2 releases. This opens the R2 front contact in the circuit between B32 and junction P2, but if the acknowledging contactor has been properly operated, energy still reaches junction P2 through whistle valve WV and ACK. CONT. X, now closed. As a result, R3 and the EPV remain energized. However, the current flow through WV causes the acknowledging whistle to sound.

With R2 down and ACK. CONT. Y closed, a circuit is established for reenergizing R1, and R1 picks up again, followed by R2. When R2 comes up, the circuit through WV and ACK. CONT. X is shunted out, and the whistle stops blowing. This indicates to the engineman that R1 and R2 are back in normal condition, and that the acknowledging contactor may be released. If he fails to do so within approximately 15 seconds after starting acknowledgment, ACK. CONT. Z opens, EPV is deenergized, and an automatic brake application follows. Since R3 is not released in this case, EPV will be reenergized as soon as the acknowledging handle is released. The engineman may then regain control of the brakes after such time penalty as may be provided in the brake system.

If a restrictive inductor is passed without acknowledgment, R1 releases, followed by R2. But now ACK. CONT. X is open, so that when R2 releases, R3 also releases, opening the stick circuit through the R3 front contact, deenergizing EPV and lighting the pilot light. The lighting of the pilot light informs the engineman that the brake application is produced by the train control system and not by some other cause. The resulting brake application cannot be released until the reset contactor has been operated, for with the R3 stick contact open the only means of reenergizing R1, R2, and R3 is through the reset contacts.

Operating the reset contactor closes the contacts which connect B32 directly to R3 and R1, and opens a contact in the EPV circuit. R3 and R1 come up, with R2 following R1, reestablishing the relay stick circuits. When the reset contactor is released, the contact in the EPV circuit closes, EPV is reenergized, and the system is restored to normal condition. Note that the reset contacts, when closed, energize R1, R3, and P, but that S is shunted out of the circuit until the reset contactor is released. This prevents S from being affected by the build-up of primary flux.

In installations in which the reset contactor is mounted in the cab within reach of the engineman, a clockwork mechanism provides a 45-second time delay after the release of the reset handle before closure of the reset contact in the EPV circuit. When this arrangement is used, the engineman may operate the reset contactor immediately after an automatic brake application has occurred, reenergizing R1, R2, and R3 at once. But since the EPV circuit is not reenergized for 45 seconds, the system still enforces an automatic stop.

Figure 716 is the same circuit as Figure 715, redrawn to show actual terminal and connection arrangements. As already mentioned, this circuit provides protection for forward running only. Forward-running protection requires a single receiver mounted on the right-hand side of the locomotive. When both forward and reverse running are desired, an additional left-hand receiver is required, together with relays for selecting the receiver to be connected into the control circuits.

SPEED GOVERNORS

Since the necessary brake application circuits are already available, addition of a speed governor to a locomotive equipped for intermittent inductive train control provides a ready means of obtaining overspeed control. Other contacts on the governor may be used to provide preliminary overspeed warning, and to prevent system reset after a train control brake application until train speed has been reduced to a pre-established low level.

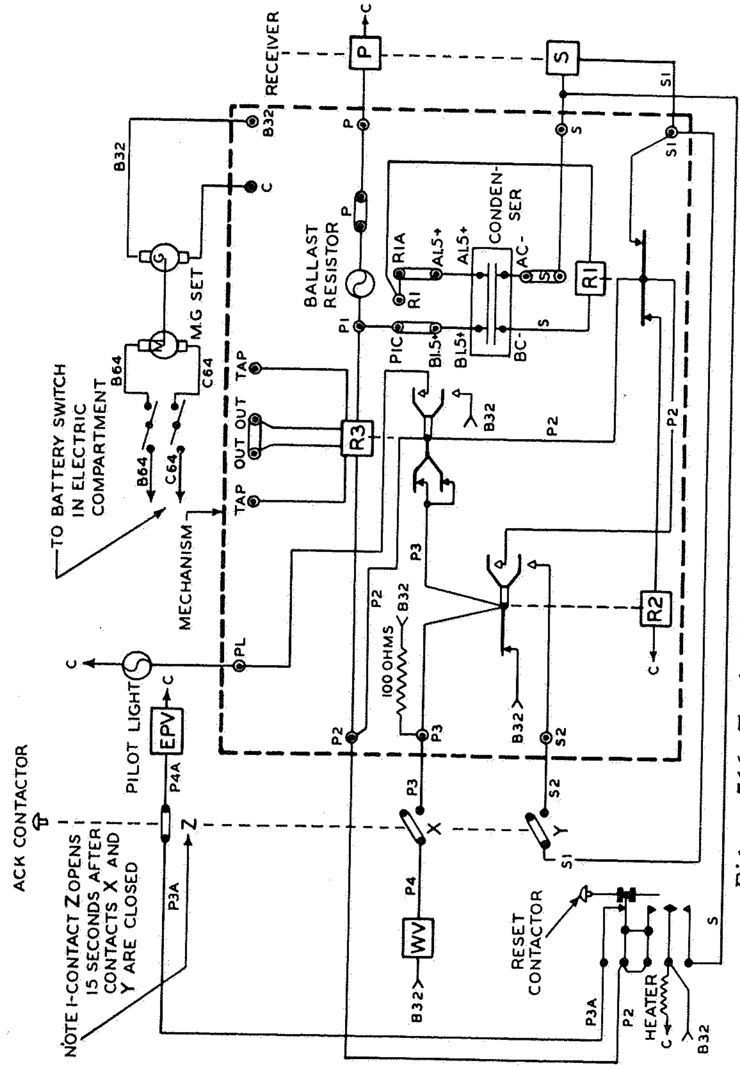

ACK CONTACTOR
NOTE I-CONTACT Z OPENS 15 SECONDS AFTER CONTACTS X AND Y ARE CLOSED
PILOT LIGHT
C
EPV
P3A
P4A
Z
TO BATTERY SWITCH IN ELECTRIC COMPARTMENT
B64
C64
MECHANISM
M.G SET
B32
PL
TAP
OUT
OUT
TAP
C
B32
RECEIVER
BALLAST RESISTOR
P1
P
P2
R3
100 OHMS
B32
P3
WV
B32
P4
X
PIC
R1
R1A
B1.5+
A1.5+
B1.5+
A1.5+
CONDEN-SER
BC-
AC-
S
RESET CONTACTOR
S1
Y
S2
B32
R1
R2
HEATER
P2
P3A
S
S1

Figure 716. Typical locomotive circuit, intermittent inductive train control.

Journal-Box Speed Governor

The journal-box speed governor, Figure 717, mounts on a locomotive journal box and is driven from the axle through a universally-jointed shaft. Rotation of the shaft operates a centrifuge assembly which, through a suitable mechanical linkage, actuates contacts as required.

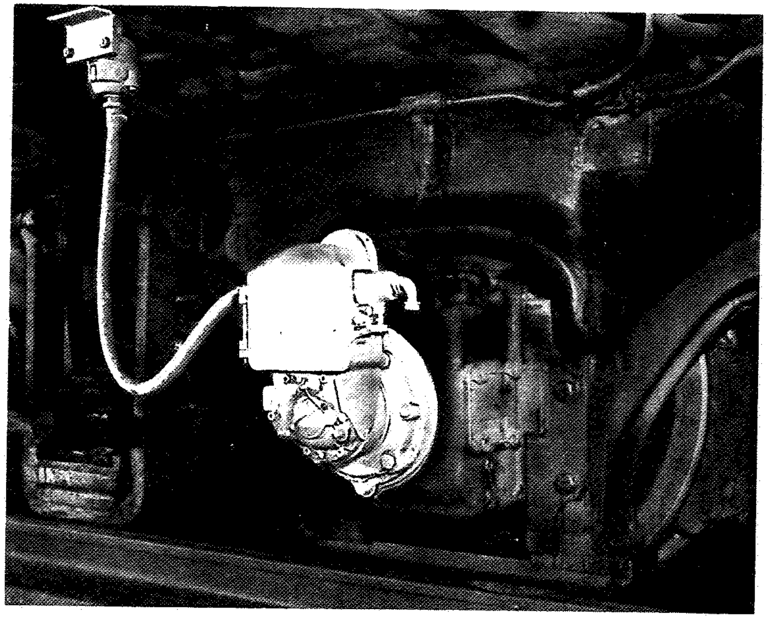
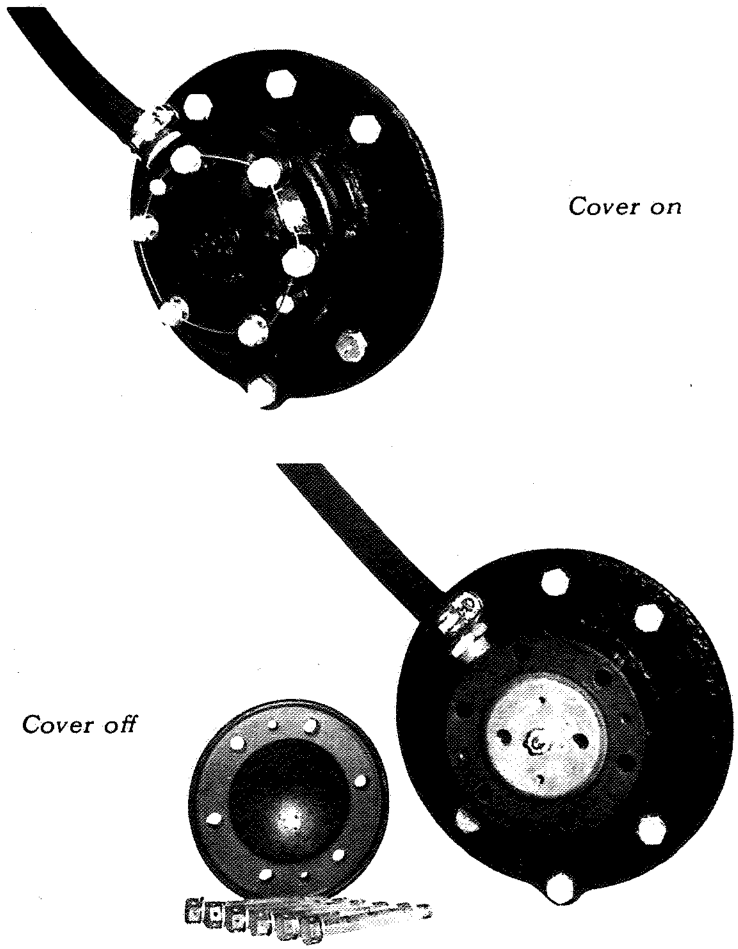


Figure 717. Journal-box speed governor.

Frequency-Responsive Speed Governor

The frequency-responsive speed governor is made up of two units: a frequency generator, and a small electronic unit.

The frequency generator, shown in Figure 718, is mounted on a locomotive journal box, and is driven from the axle through a flexible coupling. The only moving part in the whole assembly



Cover on

Cover off

Figure 718. Frequency generator for frequency-responsive speed governor.

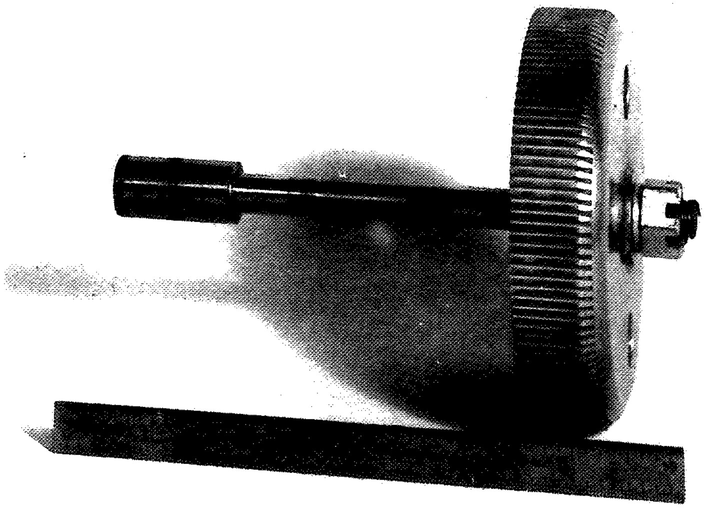
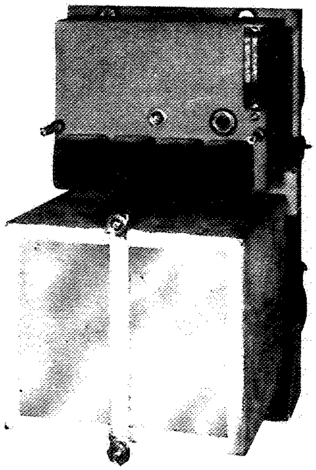


Figure 719. Rotor for frequency generator.

Figure 720. Electronic unit, frequency-responsive speed governor.



is the small, cup-shaped toothed rotor, Figure 719. No commutators, brushes, contacts, or similar devices are involved.

The rotor turns in the field of a permanent magnet, producing an a-c. output whose frequency is proportional to speed. This frequency is fed over a pair of wires to the electronic unit, Figure 720, located in any convenient position on the locomotive. The electronic unit interprets the incoming frequency in terms of speed, and controls relays accordingly.

The frequency generator, with its simple, sturdy design, is well adapted to function under the conditions of shock and vibration to which it is exposed. Coupled with mechanical ruggedness is uniform accuracy, since the frequency output is fixed by the geometry of the assembly and the axle rpm. and is not subject to variation with temperature, aging, or wear.

CONTINUOUS INDUCTIVE TRAIN CONTROL

A continuous inductive train control system automatically enforces maximum speeds consistent with block conditions. The system leaves control of the train brakes in the hands of the engineman as long as he operates within speed limits, but makes an automatic brake application if he fails to operate in accordance with requirements. If a train control brake application occurs, the engineman can at any time obtain any additional braking effect, such as emergency, which the brake system may provide. He cannot, however, release the brakes until all speed requirements and penalties of the control system have been satisfied. Release of a train control brake application is never automatic; the engineman must always follow a standard release procedure after such an application occurs, even though speed may then be below the permissible maximum.

Continuous control requires continuous transfer of information on block conditions between the wayside and the locomotive control circuits. This is accomplished by inductive linkage between the track circuit current in the rails and receivers mounted on the locomotive, exactly as done with cab signals described elsewhere in this handbook. Because of this, many of the components used in continuous control systems are the same as those used for cab signals, and a cab signal is included as part of the train control system. We may, if we wish, regard continuous train control as a cab signal system to which has been added a speed-measuring device and a brake-applying device, with circuits arranged to apply brakes when the speed-measuring device indicates the train is moving faster than is permissible under the aspect displayed by the cab signal.

It is not intended that a continuous train control system take over the engineman's control of the brakes unless necessary. Hence warning devices, such as whistles and horns, are included to inform him of an impending train control brake application, so that by taking appropriate manual brake action he may "suppress" it. On the other hand, if he fails to heed the warnings, the train control application will reduce train speed more drastically (possibly down to a complete stop) than would have been required under manual control. This serves both as an incentive to the engineman to observe the requirements of the system, and as a penalty for failure to do so.

TWO-SPEED TRAIN CONTROL SYSTEM

A typical two-speed continuous inductive train control system in use on a major American railroad provides a speed limit in clear territory of 83 mph: for passenger trains, 63 mph. for freights. In restricted territory, the speed warning whistle sounds at 20 mph. and over, and a train control brake application which enforces a train stop occurs if speed exceeds 23 mph. The components of this train control system are indicated in Figure 721.

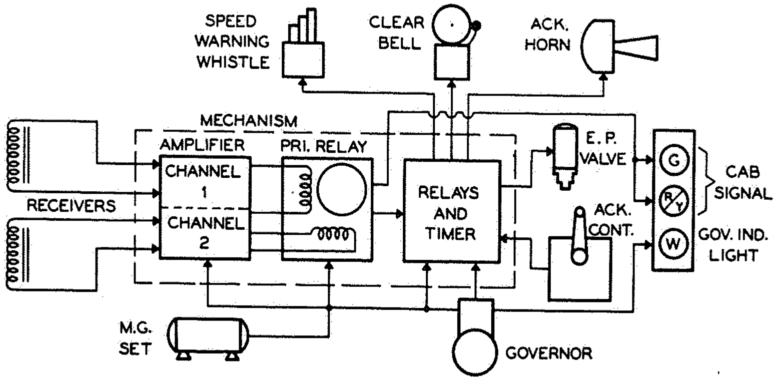


Figure 721. Components of two-speed continuous inductive train control.

Receivers

The principles of inductive transfer of track circuit energy between the running rails and locomotive receivers, and the use of a vacuum-tube amplifier to build the weak receiver voltage up to levels suitable for relay operation, are discussed in detail in the section on cab signals. Illustrations of typical receivers are shown in the same section. The receivers and amplifier for the two-speed train control system, although different in details, operate on the same general principles.

In the two-speed system, coded track circuits are not used. Instead, the clear block condition is indicated by 60-cycle a.c. "on" in the track circuit, and the restrictive condition by energy "off." The use of 60-cycle energy and the absence of coding make it necessary to provide protection against foreign a.c. in the rails. This is achieved by amplifying the output of each receiver coil separately in an independent amplifier channel, thus producing two amplified outputs which have the proper phase relationship. These outputs are fed separately to the two windings of a two-phase primary relay. The primary relay has a rotary armature, spring-biased to the restrictive position, which will not rotate to close its front (clear) contacts unless the two-phase windings are energized in the proper phase relationship. The condition necessary for this is that the rail a.c. inducing the receiver voltages must be flowing in opposite directions in each rail at any instant. When current flow is "down" the left-hand rail, it must be "up" the right-hand rail, and vice versa. As a result, current flowing in only one rail, or in parallel in both rails, will not cause the relay to operate. But track circuit a.c. flows toward the train through one rail, shunts through the locomotive wheels and axles, and flows away from the train through the other rail. This meets the phase requirements of the system, and the primary relay makes its front contacts when track circuit a.c. is present in the rails.

Cab Signal and Governor Indicator Light

The cab signal provides two aspects: green for the clear indication, red-over-yellow for restricting. Included in the same housing as the cab signal is a white light which lights at speeds of 20 mph. or greater to indicate that the governor is operating.

Speed Warning Whistle

The speed warning whistle sounds in clear territory when speed exceeds 83 mph. (passenger) or 63 mph. (freight). In restrictive territory, the whistle sounds on both passenger and freight trains when speed exceeds 20 mph. The whistle is similar in appearance to the acknowledging whistle used with the intermittent inductive system, Figure 711.

Clear Bell

The clear bell rings momentarily each time block conditions change from restrictive to clear. This attracts the engineman's attention to the new block conditions so that he may take prompt advantage of the improved situation.

Acknowledging Horn

The acknowledging horn sounds when a train enters restrictive territory (after speed has been sufficiently reduced) and periodically thereafter while the train is proceeding under restrictive conditions. The horn informs the engineman that an operation of the acknowledging contactor is required.

Acknowledging Contactor

The acknowledging contactor must be operated by the engineman each time the acknowledging horn sounds to prove his alertness to restrictive conditions. Acknowledgment must be made within five seconds of the time the horn sounds, under penalty of a train control brake application which will stop the train before it can be released. Proper acknowledgment silences the acknowledging horn and allows the engineman to retain control of the brakes, provided he does not violate the restrictive territory speed limit.

Governor

The speed governor may be of either the journal-box or frequency-responsive type described previously for use with intermittent train control systems. The governor opens and closes contacts at various speeds as required by the system, thus providing the necessary speed information to the control circuits.

Electro-Pneumatic Valve

The electro-pneumatic valve is of the same general design as described for the intermittent inductive system. When deenergized, it opens an air line which causes the brake application valve in the air brake system to initiate a brake application.

The air brake system used with two-speed train control distinguishes between brake applications initiated by the engineman and brake applications initiated by the electro-pneumatic valve. A penalty in the form of more severe application and delayed release is imposed on the latter. Such penalties are "suppressed" if adequate manual brake application is made before the electro-pneumatic valve is deenergized, even though the valve does release subsequently.

Motor-Generator Set

The motor-generator set performs two functions. It converts the locomotive supply voltage to the 32 volts required by the train control system, and it provides electrical isolation of the train control system from other circuits fed by the locomotive supply.

Mechanism

The mechanism consists of: (1) the electronic amplifier for the receivers; (2) the primary relay; (3) the relays associated with the audible indicators, electro-pneumatic valve, and acknowledgment; (4) a motor-operated timing unit which operates time-delay contacts required by the system. These devices are shock-mounted in a rugged steel mechanism case, located in any convenient location on the locomotive. Plug-connection is used throughout for ease of maintenance.

OPERATION—TWO-SPEED SYSTEM

For ease of explanation, it is convenient to consider separately the operation of the two-speed continuous inductive train control system under the various block and speed conditions that may be encountered.

Overspeed—Clear Territory

In clear territory (green signal aspect), when train speed exceeds 83 mph. for passenger trains, or 63 mph. for freights, the speed warning whistle sounds, followed in approximately six seconds by a train control brake application. The engineman may escape brake release penalties involved in a train control application by "suppressing," i.e., by making a manual 20-pound brake-pipe reduction. Because of time relationships in the operation of the system, "suppression," to be effective, must occur within five seconds of the sounding of the whistle.

If a train control application does occur, the engineman must first move the brake valve handle to lap position, and then must wait to release the brakes until after the speed warning whistle has stopped and a penalty delay has expired. The resultant brake application will exceed the 20-pound manual brake application required for "suppression," and there will also be a penalty delay of approximately 12 seconds in obtaining release. The net effect is to impose a more severe train speed reduction than would occur with the manual reduction. Failure of the engineman to move the brake valve handle promptly to lap position when a train control application occurs increases the penalty effects.

Overspeed—Restrictive Territory

In restrictive territory (red-over-yellow signal aspect), the speed warning whistle sounds when speed exceeds 20 mph., but no penalty is imposed. If speed continues to increase to 23 mph., a train control brake application occurs which will stop the train before brake release can be effective.

Change of Indication—Clear to Restricting

If train speed is above 33 mph. when the indication changes from clear to restricting, the speed warning whistle sounds, and the engineman must "suppress" within five seconds. When the speed reaches 33 mph. the acknowledging horn sounds, and an acknowledgment is required. After acknowledgment is made, brakes may be released. However, train speed must be further reduced to 23 mph. within 75 seconds of the time of acknowledgment, or a train control brake application will result. The speed warning whistle continues to sound until speed drops to 20 mph. The preliminary release at 33 mph. gives trains (especially freights which have made prolonged brake applications in reducing speed) time to get brakes off before a full stop occurs. This 75-second period during which train speed may exceed 23 mph. in restrictive territory occurs only once after each change from a clear to restrictive indication. After this period has expired, train speed in excess of 23 mph. will result in a train control application which results in a complete stop as described previously.

If speed is between 33 and 23 mph. when the restrictive aspect occurs, both the speed warning whistle and acknowledging horn sound immediately. An acknowledgment is required within five seconds, after which a 75-second period is provided in which speed must be reduced to 23 mph. by any convenient means, such as shutting off, dynamic brakes, independent brakes, or by a light service application.

Operation in Restrictive Territory

While operating in restrictive territory, the engineman is required to acknowledge every 100 seconds after the first acknowledgment, as indicated by the acknowledging horn. Failure to acknowledge within five seconds after the horn sounds results in a train control brake application which will stop the train.

When the train is standing in restrictive territory with a pressure of 35 pounds per square inch in the locomotive brake cylinders, recurrent acknowledgment is not required. However, the engineman must acknowledge prior to proceeding.

Change of Indication—Restricting to Clear

A change of indication to clear causes the clear bell to sound momentarily to call the engineman's attention to the change. Regardless of prior penalty requirements, a change to clear permits brake release to be initiated at any time by moving the brake valve handle to lap position and then to release.

LOCOMOTIVE CIRCUITS—TWO-SPEED SYSTEM

Figure 722 shows a circuit used to obtain the two-speed control described previously. The circuit, as drawn, is arranged to enforce the 63 mph. freight-train maximum; the passenger-train maximum of 83 mph. may be obtained by closing the speed selector switch. Primary relay contacts and governor contacts are shown in the position for a train proceeding in clear territory at a speed between 33 and 63 mph.

Clear Territory—Speed Between 33 and 63 Mph.

In clear territory, with speed between 33 and 63 mph., the primary relay is energized, governor contacts 3L and 4R are closed, and governor contacts 1R, 4L, 1L are open. (Governor contact 2R is also closed, but is inoperative in the circuit with the speed selector switch open and will be ignored hereafter.) With the primary relay energized, the green signal aspect is lighted from B32 through primary relay contact 4N, and the white governor indicator light is lighted through governor contact 4R. Primary repeater relay PRP is up, energized from B32 through primary relay contact 3N, acknowledgment repeater relay ACP contact 12/11, and primary relay contact 2N Likewise, governor repeater relay GP is up, energized through governor contact 3L and PRP contact 16/15. With PRP and GP up, slow-acting relay SA1 is up, energized by a circuit through PRP contact 25/26, GP contact 35/36, AR contact 34/35, SA1 coil, AR contact 32/31 and PRP contact 13/12. With SA1 up, slow-acting relay SA2 is also up, the energizing circuit being through SA1 contact 25/26, SA2 coil, and SA1 contact 24/23. SA2, in turn, controls energy to the electropneumatic valve EPV through SA2 contact 25/26, EPV coil, and SA2 contact 24/23.

Note that EPV is energized whenever SA2 is up, and that SA2 is energized whenever SA1 is up. EPV is therefore controlled by SA1 through SA2. SA1 and SA2 are identical slow-release relays with a release delay of about three seconds each. Hence EPV is deenergized approximately six seconds after energy is removed from SA1.

Under the conditions specified (clear territory, speed under

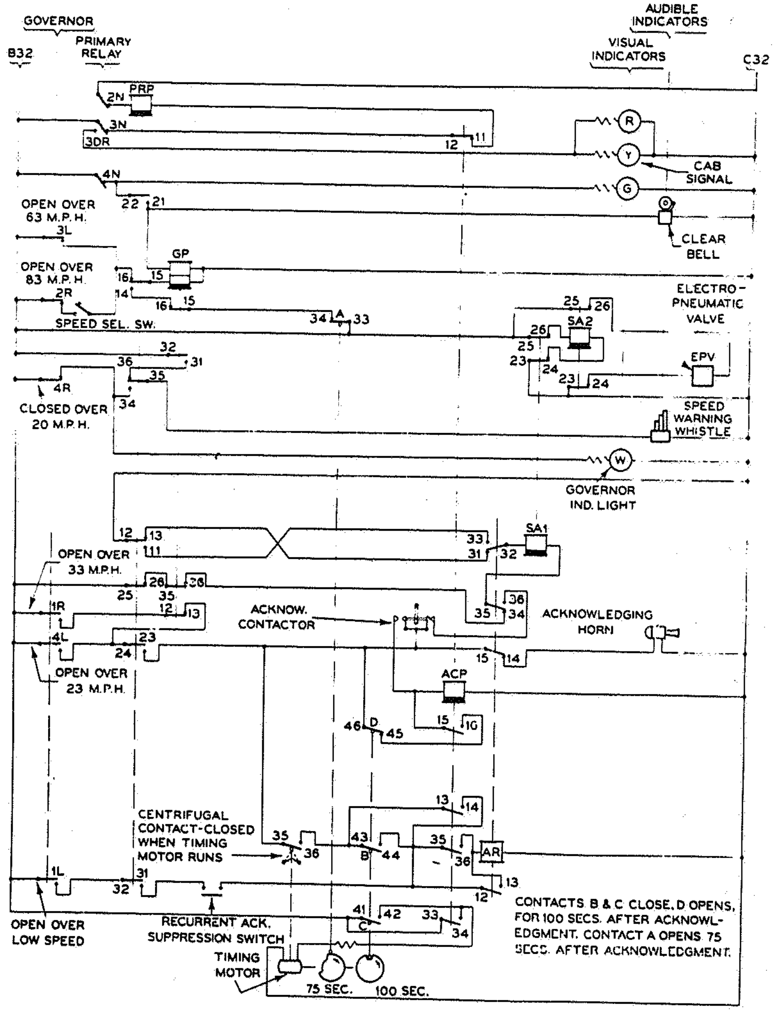

GOVERNOR
PRIMARY RELAY
B32
AUDIBLE INDICATORS
VISUAL INDICATORS
C32
PRP
2N
3N
3DR
4N
R
Y
G
CAB SIGNAL
OPEN OVER 63 M.P.H.
3L
CLEAR BELL
GP
OPEN OVER 83 M.P.H.
2R
SPEED SEL. SW.
ELECTRO-PNEUMATIC VALVE
SA2
EPV
4R
CLOSED OVER 20 M.P.H.
SPEED WARNING WHISTLE
W
GOVERNOR IND. LIGHT
SA1
OPEN OVER 33 M.P.H.
1R
4L
OPEN OVER 23 M.P.H.
ACKNOW. CONTACTOR
ACKNOWLEDGING HORN
ACP
CENTRIFUGAL CONTACT-CLOSED WHEN TIMING MOTOR RUNS
AR
1L
OPEN OVER LOW SPEED
RECURRENT ACK. SUPPRESSION SWITCH
TIMING MOTOR
75 SEC.
100 SEC.
CONTACTS B & C CLOSE, D OPENS, FOR 100 SECS. AFTER ACKNOWLEDGMENT. CONTACT A OPENS 75 SECS. AFTER ACKNOWLEDGMENT.

Figure 722. Typical circuit, two-speed continuous inductive train control.

63 mph.) all other relays are released, the timing motor is not running, none of the audible indicators is energized, and operation of the acknowledging contactor has no effect.

Clear Territory—Overspeed

If train speed exceeds 63 mph. in clear territory, governor contact 3L opens, and GP, which is slightly slow release, releases after a short delay. Release of GP sounds the speed warning whistle, with energy from B32 through GP contact 32/31 and PRP contact 36/35. GP contact 35/36 also opens, removing energy from SA1. Approximately six seconds later EPV is deenergized, as already described, and a train control brake application ensues unless the engineman has "suppressed" soon enough (about five seconds) after the speed whistle sounds by making a manual brake application.

If the engineman "suppresses" in time, EPV still releases at the end of six seconds, but the prior manual application avoids the brake release penalty delay which otherwise results from an EPV brake application.

When speed drops below 63 mph., governor contact 3L closes, and GP picks up, followed by SA1, SA2, and EPV. The whistle is silenced, and the engineman may release the brakes by turning the brake valve handle to lap and then to release.

Entering Restrictive Territory—33 to 63 Mph.

If the train enters restrictive territory at a speed between 33 and 63 mph., governor contacts 3L and 4R are closed, and 1R, 4L, and 1L are open when the primary relay releases. Upon release of the primary relay, primary relay contact 4N opens, extinguishing the green cab signal aspect, and contact 3DR closes, lighting the red-over-yellow aspect. At the same time, opening of primary relay contacts 3N and 2N deenergizes PRP, which releases. Release of PRP causes the speed warning whistle to sound, energized through governor contact 4R and PRP contact 34/35. The whistle will now continue to sound until governor contact 4R opens at 20 mph. The energy circuit to SA1 is also opened at PRP contact 25/26, so that EPV is deenergized about six seconds later. Release of EPV produces a train control brake application unless the engineman has "suppressed," as already described.

Although GP is normally energized through PRP contact 16/15, release of PRP does not cause GP to release. This is because GP is slow-release, and remains up while PRP crosses from its front to back contacts. With PRP back contacts made, GP remains up through the stick circuit from B32 through 75-second timing contact A, GP contact 15/16, and PRP contact 14/15.

The brakes have now been applied, either manually or through EPV, and speed is reduced. When 33 mph. is reached, governor contact 1R closes, and the acknowledging horn sounds, energized through governor contact 1R, GP contact 12/13, PRP contact 24/23, and acknowledging relay AR contact 15/14. Energy is also applied to the acknowledging contactor at this time through the first portion of the same circuit.

Acknowledgment energizes ACP, which sticks up through 100-second timing contact D and its own contact 16/15, thus remaining energized even though the acknowledging contactor is released. When ACP picks up, the timing motor starts, energized through ACP contact 33/34. With the motor running, centrifugal contact 35/36 closes, proving that the motor is operating, and that timing requirements will therefore be properly enforced.

Closing of centrifugal contact 35/36 energizes AR, with current flowing from B32 through governor contact 1R, GP contact 12/13, PRP contact 24/23, centrifugal contact 35/36, ACP contacts 13/14 and 35/36, and the coil of AR to C32. When AR picks up, it sticks up through its contact 12/13, and silences the acknowledging horn by opening its contact 15/14.

Shortly after the timing motor starts, the cam follower on the 100-second cam rides up out of the notch, opening timing contact D, and closing timing contacts B and C. The stick circuit on ACP is opened when contact D opens, but since ACP is somewhat slow-release, the ACP contacts do not open until there has been adequate time for timing contacts B, C, and D to have been actuated fully. With 100-second contact C closed, the motor continues operating after ACP releases. With timing contact B closed, the stick circuit on AR, originally obtained through ACP contact 13/14, is maintained.

With AR picked up, return of the acknowledging contactor to its normal position now energizes SA1 through governor contact 1R, GP contact 12/13, PRP contact 24/23, the normally-closed acknowledging contact, AR contact 36/35, SA1 coil, AR contact 32/33, and PRP contact 11/12. SA2 and EPV follow SA1. With EPV reenergized, brake release may be obtained in the usual way.

After 75 seconds, the cam follower on the 75-second cam drops into the notch on the cam. Timing contact A opens, and with it the stick circuit on GP. GP therefore releases shortly after. This opens GP contact 12/13, which is in the circuit used to energize AR and SA1 in obtaining 33-mph. brake release. However, if speed has by now been reduced to 23 mph., governor contact 4L is closed, and the circuit through this contact provides a path around the open GP contact 12/13. Note that the release of GP isolates governor contact 1R, so that the 33-mph. preliminary brake release is obtainable only once for each change from clear to restrictive territory. (The 75-second timing contact A continues to operate after first acknowledgment, but has no circuit effect after the first revolution of the cam.)

Meanwhile, the timing cams continue to rotate, and 100 seconds after first acknowledgment timing contacts B and C open, and contact D closes. Opening of contact C stops the timing motor; opening of contact B deenergizes AR, which releases. With AR released, the acknowledging horn sounds, energized through governor contact 4L, PRP contact 24/23, and AR contact 15/14. SA1 is also deenergized by the release of AR, starting the six-second delay period for release of EPV.

Acknowledgment energizes ACP as before, followed by the timing motor and AR, with pick-up of the latter silencing the acknowledging horn and reenergizing SA1. The cycle is thus restarted, and will repeat every 100 seconds while the train is proceeding in restrictive territory.

Note that the normally-closed acknowledging contact is, under restrictive conditions, included in the circuit energizing SA1. Any attempt to circumvent the acknowledgment requirement by blocking the acknowledging handle makes it impossible to keep EPV energized, and hence results in a train control brake application.

Penalty Stops—Restrictive Territory

When a train is proceeding in restrictive territory, the speed warning whistle sounds each time speed exceeds 20 mph., energized through governor contact 4R and PRP contact 34/35. This indicates to the engineman that speed is within three mph. of the maximum. If speed increases beyond 23 mph., governor contact 4L opens, opening the circuit through which SA1 is energized. Six seconds later EPV releases and a train control brake application results. At the relatively low speed at which the train is moving, the delayed brake release penalty provided by the brake system then ensures that the train will be completely stopped before brake release can be effective.

Failure to acknowledge as required by the system results in the same penalty, since such failure also results in a train control brake application at low speed.

Suppression of Recurrent Acknowledgment

When the train is standing still (as at a station) in restrictive territory, with a pressure of 35 pounds per square inch in the locomotive brake cylinders, acknowledgment need be made only once; recurrent acknowledgment is not required. Under these conditions, governor contact 1L is closed, as is the recurrent acknowledgment suppression switch, which closes when locomotive brake cylinder pressure reaches 35 pounds per square inch. When one acknowledgment is made under these conditions, AR picks up, but now the stick circuit through AR contact 12/13 is maintained through governor contact 1L, PRP contact 32/31, and the recurrent acknowledgment suppression switch. AR is thus held up when the 100-second timing contacts open and the timing motor stops.

Upon releasing the locomotive brakes when ready to proceed, the acknowledging horn sounds, and acknowledgment is required before proceeding.

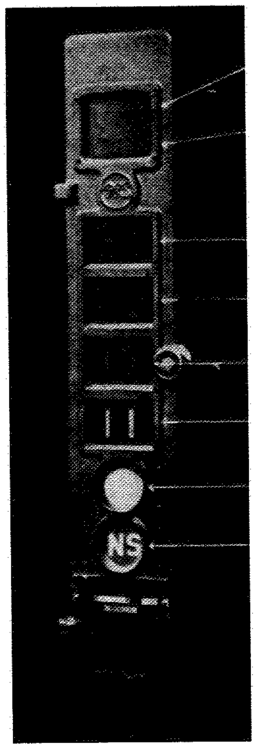
Change of Indication—Restricting to Clear

When the locomotive enters clear territory, the primary relay is energized and closes contacts 2N, 3N, and 4N. PRP follows, after the slight pick-up delay characteristic of slow-release relays. During this brief delay period, the clear bell rings, energized through primary relay contact 4N and PRP contact 22/21. When PRP comes up, the clear bell is silenced.

Preliminary energization of GP also occurs through primary relay contact 4N and PRP contact 22/21, with GP finally coming up through governor contact 3L and PRP contact 16/15.

MULTI-SPEED TRAIN CONTROL SYSTEMS

We have seen how, using inductive transfer of information by track circuit energy "on" or "off," a two-speed train control system operates. We also know (see section on Cab Signals) that we can increase the information available to the locomotive circuits by using coded track circuits. Thus a train control system may be devised which enforces not just two, but a series of speed limits. For example, we can, if we wish, enforce four different speed limits in conformance with the clear, approach medium, approach, and restricting aspects of the associated cab signal.



Bell—Warning when maximum permissible speed is exceeded. If not observed, system applies brakes.

Buzzer—Motorman must acknowledge "Red 11" signal when it appears.

Permissible Speed Indication—Green—35 miles per hour.

Permissible Speed Indication—Yellow and Green—25 miles per hour.

Permissible Speed Indication—Yellow—17 miles per hour.

Permissible Speed Indication—Red—11 miles per hour.

White Speed Indicator—Lighted when at maximum permissible speed.

Violet NS Indicator—Lighted when in non-signaled territory.

Figure 723. Cab signal, four-speed continuous inductive train control.

Four-speed System

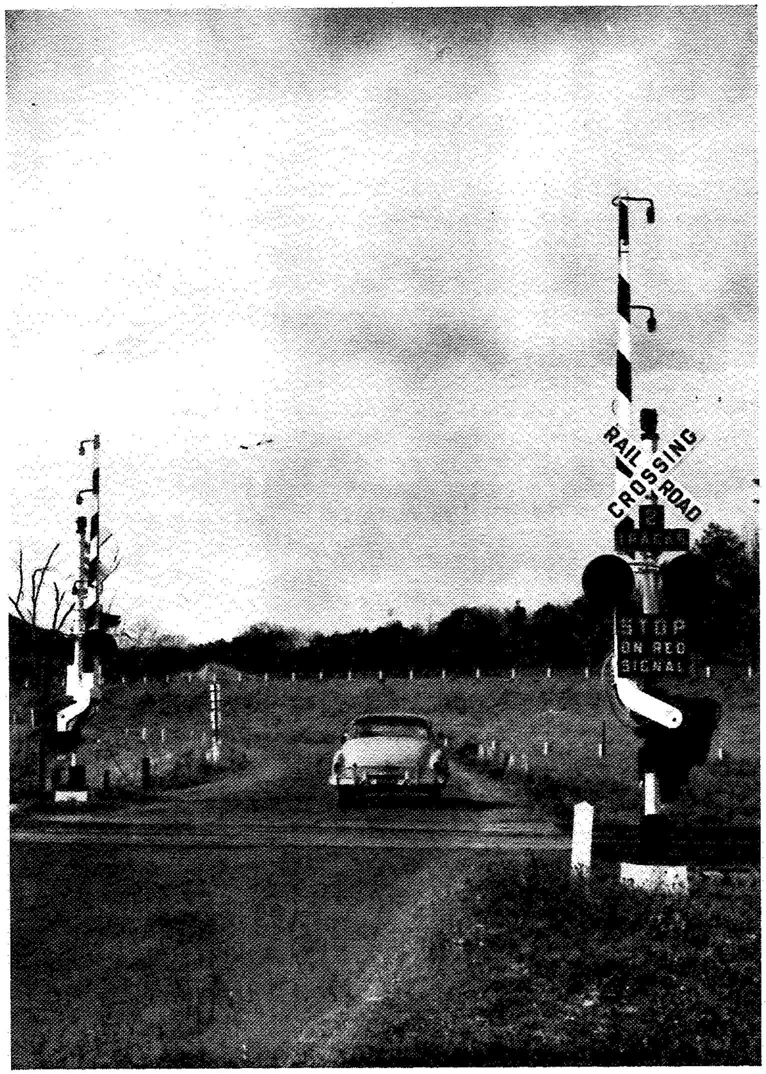
Figure 723 shows the cab signal for a four-speed continuous inductive train control system. In this particular installation (a suburban line using multiple-unit cars) the signal aspect combines the aspect color with a direct display of the maximum speed permitted when that aspect is displayed.

A bell and a buzzer are included in the upper part of the cab signal housing. The bell is an overspeed warning. The buzzer sounds each time the "Red 11" signal is displayed, and requires operation of an acknowledging contactor under penalty of an automatic brake application that will stop the train.

The white light in the cab signal housing lights when the train is traveling at the maximum speed permissible for the signal displayed. If this speed is exceeded by one mile per hour, the warning bell rings, and a manual brake application must be made promptly to suppress a train control brake application.

When the existent authorized speed changes to a lower authorized speed, and the train is traveling above the new speed limit, power must be shut off and a service brake application made within 2½ seconds to avoid a train control brake application.

A multi-speed train control system, because of the finer gradations of train speed provided, permits trains to follow each other with closer spacings than is permissible with a two-speed system. Thus a multi-speed system would be indicated for lines in which traffic was sufficiently heavy to justify the additional complexity of the multi-speed system, while a two-speed system would be adequate for lines handling lighter traffic. Both systems ensure that train speeds are appropriate at all times to block and track conditions ahead.



HIGHWAY CROSSING PROTECTION

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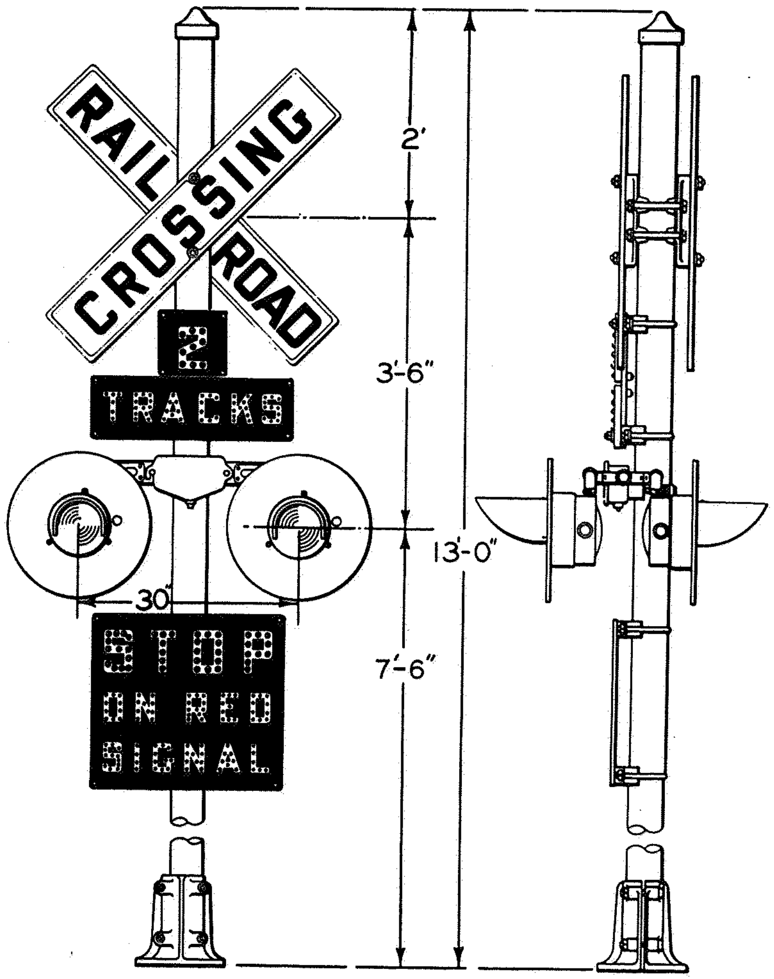

Figure 801. Highway crossing signal equipped with four Type XC light units, cast iron crossbuck, and reflector type stop and track signs.

FLASHING LIGHT CROSSING SIGNALS

TYPICAL ARRANGEMENTS

Flashing light signals are produced in a number of types, to display in one direction only or in two or more directions, with illuminated STOP signs or with reflector button signs indicating STOP ON RED SIGNAL, with reflector or cast iron crossbuck signs, and with track number signs, cast iron or reflector as required. Figure 801 shows a typical arrangement.

The signal mast is usually fifteen feet from the nearest rail, and six feet from the edge of the highway. It is general practice to locate two four-unit signals per crossing with lights on each to flash in both directions at 40 to 45 flashes per minute. Roundels may have a light spread of from 30° to 160° and a downward deflection of from 0° to 32° as required. Lamp bulbs may be 13.3 to 25 watts at 11.3 volts rating. Lamps of 30° spread shall be visible not less than 1500 feet in bright sunlight. Wide angle lamps will not be visible this far. Lamps may be equipped with Phankill units to reduce apparent illumination from reflected light (called "phantom indication") and with wire mesh guards for protection.

The standard signal mast is of 4-inch I. D. pipe, thirteen feet above the top of the rail. The length must be increased 18 inches for each additional crossarm. On account of obstructions, it is sometimes necessary to mount the lamps on cantilever masts, the arms to extend 5 feet to 12 feet over the street at a height of not less than 14 feet. This type is also equipped with standard signs. Figure 802 shows a cantilever arm in addition to the regular signals.

Standard masts may be mounted on the instrument housing, but this is not favored due to the damage that may result from a traffic accident. Housings, as a rule, are located about 25 feet from the highway and 15 to 20 feet from the nearest rail or

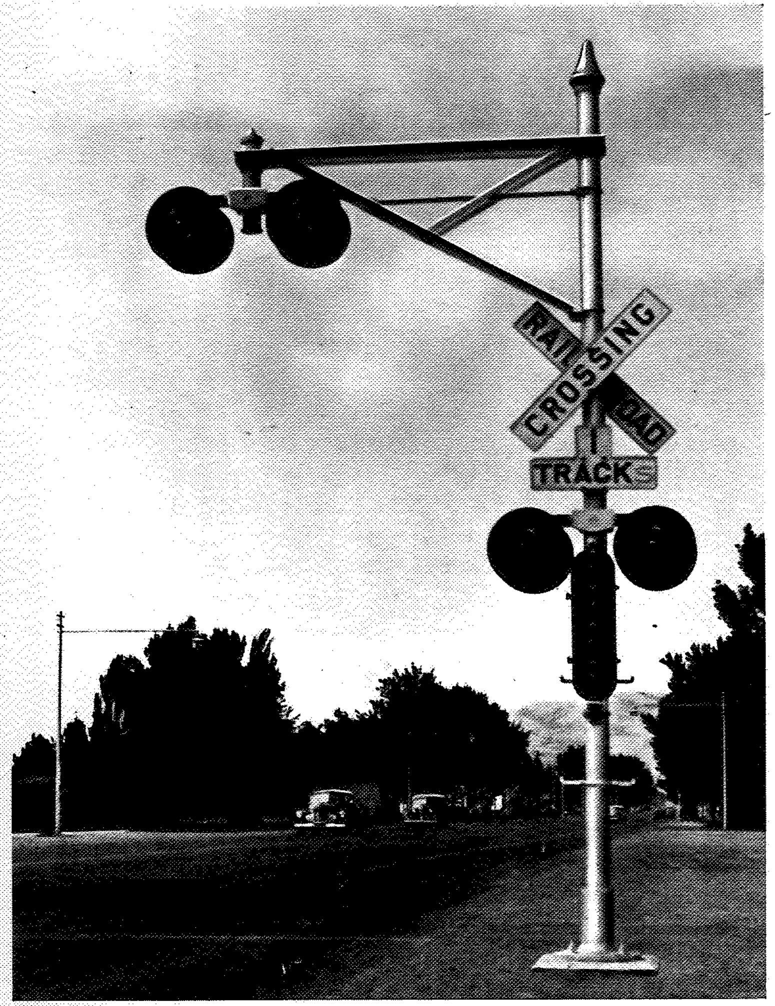

Figure 802. Highway crossing signals with illuminated stop sign and cantilever arm.

where room is available. Underground cables feed the signals and track circuits, and a 3-inch pipe should be run under the street to protect them.

Advance warning signs are installed off the railroad right of way and are considered as the responsibility of the highway department.

Most highway signals have a reflector button sign below the crossarm, reading **STOP ON RED SIGNAL**, but sometimes the illuminated stop sign, Figure 802, is preferred. These have a steady burning lamp bulb behind each letter in the word **STOP**. Two of these signs take about 8 amperes. In case of a-c. power failure, this added load is considered too heavy for a battery if the outage is long sustained. Therefore, these illuminated signs are usually fed from a.c. only and are dark if the power is off. In such a circumstance, the flashing lights only are relied on for warning until power is restored.

CONTROL CIRCUITS

Track control circuits for all protective systems in general are similar but vary widely in detail for individual locations due to switching, station stops, multiple tracks, etc.

Type K Interlocking Relay

On single track, or on multiple track where trains are operated in both directions, the track circuit control system must be arranged to clear the crossing signals as soon as the train is off the highway intersection—regardless of the direction of train operation. A Type K interlocking relay, Figure 803, is one device that can be used to accomplish this. Referring to Figure 804, we see the mechanical linkage of the interlocking mechanism before a train appears in the picture. Both armatures are up and cams L and R are both at rest. As a train comes on the track circuit from the west, the left-hand armature drops and closes its back contacts. At the same time a projection on the armature bears on cam L, turning it so that the foot of

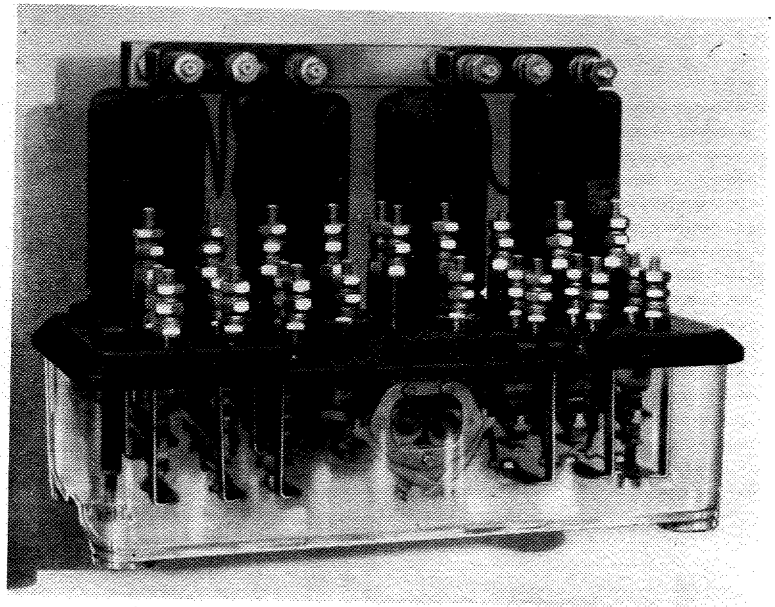

Figure 803. Type K interlocking relay.

cam L is in a position to block the rotation of cam R. As the train passes across the highway crossing and on to the easterly track circuit, the right-hand armature drops, opening its front contacts. It cannot make its back contacts because of the mechanical interference of the foot of cam L which is resting against the leg of cam R. Since the back contacts cannot be made on the right-hand armature, the highway crossing signals will cease flashing as soon as the last car of the train clears the crossing. Even after the left-hand armature picks up, the right-hand armature is still prevented from making its back contacts because the weight of the right-hand armature is still forcing cam R against the foot of cam L. A toe on the foot of cam R prevents cam L from dropping off the end of cam R. There is

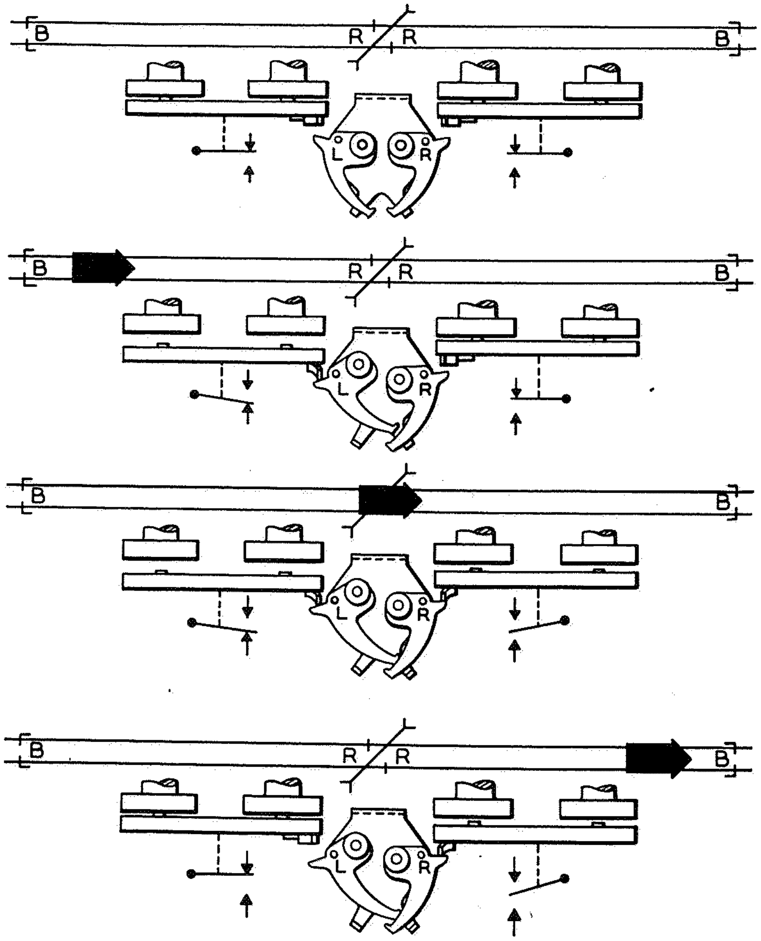

Figure 804. Sequence of operation of mechanism on Type K interlocking relay as a train moves from west to east.

also a stop to prevent cam **R** from revolving more than a predetermined distance, which means that cam **R** could not revolve enough to cause the right-hand armature to make its front contacts.

When a train comes on the circuit from the opposite direction the same action takes place except that the sequence is reversed.

Control Circuit with Interlocking Relay

Simplified circuits illustrating the use of an interlocking relay to control flashing-light signals are shown in Figure 805. Circuits **1T** and **2T** control the crossing flashers. They are staggered to include the highway crossing. When an eastbound train shunts **1T**, the **1T** side of the interlocking relay drops, sending current from **BL** through the left-hand contact to flasher relay **F**, which immediately starts the flashing lights on the highway crossing signal. The other **1T** back contact completes a circuit to shunt out the top insulated joint, thus extending track circuit **1T** as far as the bottom insulated joint—across the highway. Thus the signal will continue flashing until the last car of the train has cleared the insulated joint on the bottom rail.

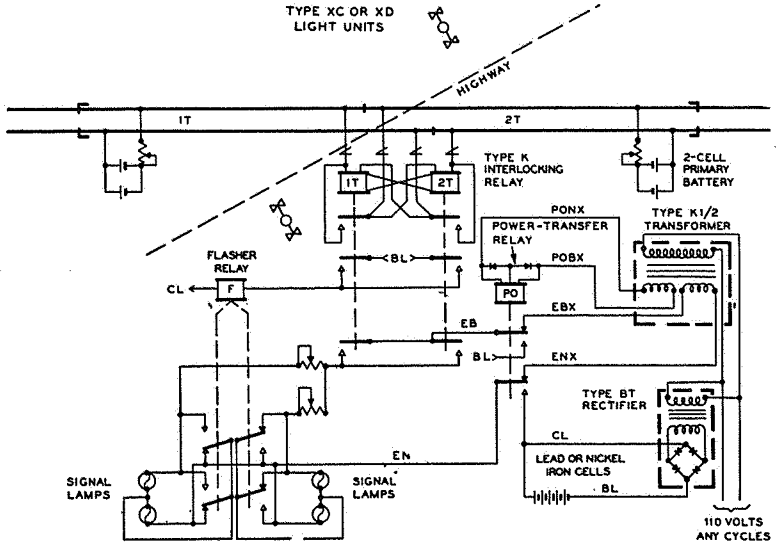

Figure 805. Circuit showing use of interlocking relay to control flashing light signals.

As the train continues into section **2T**, contacts on relay **2T** will drop, but because of the construction of the interlocking relay previously explained, the backs on **2T** will not be made. Therefore, when the last car of the eastbound train clears the insulated joint on the bottom rail, the highway crossing signal will cease to flash and will continue dark until the next train comes along—from either direction.

When a westbound train approaches from the right, the sequence of operation is reversed.

The circuit shows a source of 110 volts a.c. which is fed to the battery on floating charge through a rectifier. There is also a Type K½ transformer in the circuit. One secondary of this transformer feeds the filaments of the lamps on the highway crossing signal with a-c. current. The other secondary feeds the power-transfer relay. If the commercial power falls too low for an adequate aspect, the power-transfer relay drops, and the circuit is transferred entirely to d-c. operation.

Stick-Circuit Control

As shown in Figure 804, one side of the interlocking relay does not achieve full opening of the front contact—a condition not considered desirable for automatic block signal protection. Figure 806, although shown as for a non-signaled road, illustrates the use of standard track relays instead of an interlocking relay at a highway crossing. This circuit also shows an arrangement for clearing the crossing signals if a train remains too long on an approach track—as when stopping at the station.

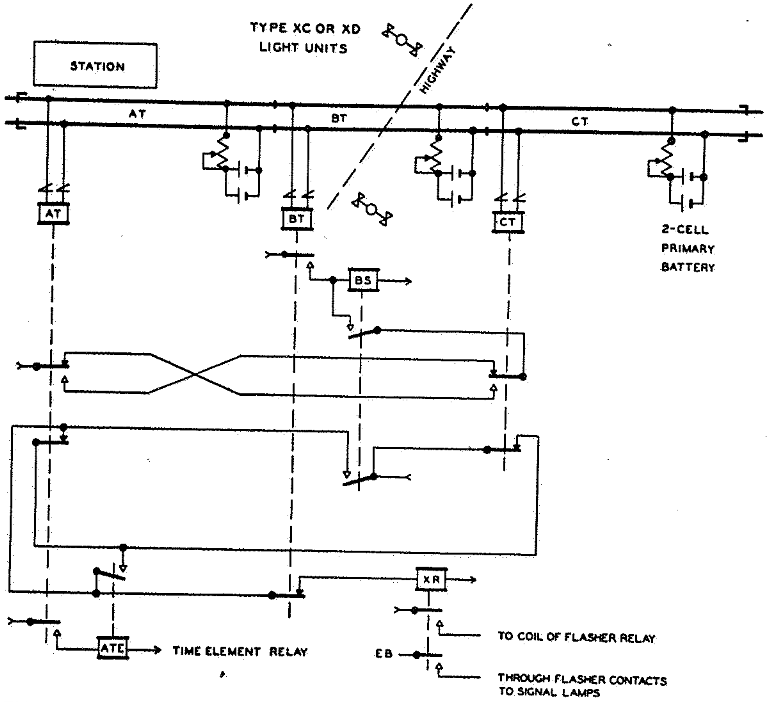

Figure 806. Circuit showing use of stick relay to control flashing light signals.

Whenever relay **XR** is down, the flashing signals operate. As shown, **XR** is fed energy from the heel of **BS**, through **CT** front, **AT** front, and **BT** front. As soon as an eastbound train drops **AT**, **XR** drops, and the flashers operate.

When **BT** drops, **BS** picks up through **BT** back. When the train clears track circuit **AT** and **AT** picks up, the circuit to **XR** remains open at **BT** front.

When **CT** drops, an additional stick circuit to **BS** is established through **AT** front, **CT** back, and **BS** front. When the train clears track circuit **BT**, **XR** is energized through **BS** front and **BT** front, and the flashers cease to operate.

When the train passes off track circuit **CT**, the feed to **BS** is broken at **CT** back, and **XR** is held energized as shown (**BS** is sufficiently slow release to bridge the crossover time of the contacts of **CT**).

A westbound train first shunts **CT**, opening the circuit to **XR** through **CT** front contacts. Next, the train occupies **BT**, and **BS** is picked up through **BT** back. When the train clears **CT**, the circuit to **XR** is kept open at **BT** front. As soon as the westbound train clears **BT**, energy is fed to **XR** through **BS** front and **BT** front, thus stopping the flashers. **BS** is held energized through **AT** back, **CT** front, and its own front. When the train clears **AT**, the circuit to **BT** is opened at **AT** back, and **XR** remains energized through circuit as shown.

Automatic Cutout

When an eastbound train enters track circuit **AT**, energy is fed through **AT** back to time element relay **ATE**. If the train remains at the station long enough for **ATE** to close its front contact, **XR** is again picked up, the circuit being through **BS** heel, **CT** front, **ATE** front, and **BT** front to **XR**. Thus the flashers cease to operate until the train starts up again and shunts track circuit **BT**.

At train departure time, the engine moves slowly out of the station and starts the crossing signals flashing as soon as the engine hits section **BT**. This gives traffic at the crossing sufficient warning as the train has not picked up headway and is, therefore, moving slowly when it hits track section **BT**.

Half-Wave Rectified Control Circuit

Figure 807 shows another circuit for use in non-signaled territory where alternating current is available. This is a half-wave rectified track circuit, well adapted for crossing signal control. It has the advantage of concentrating at the crossing

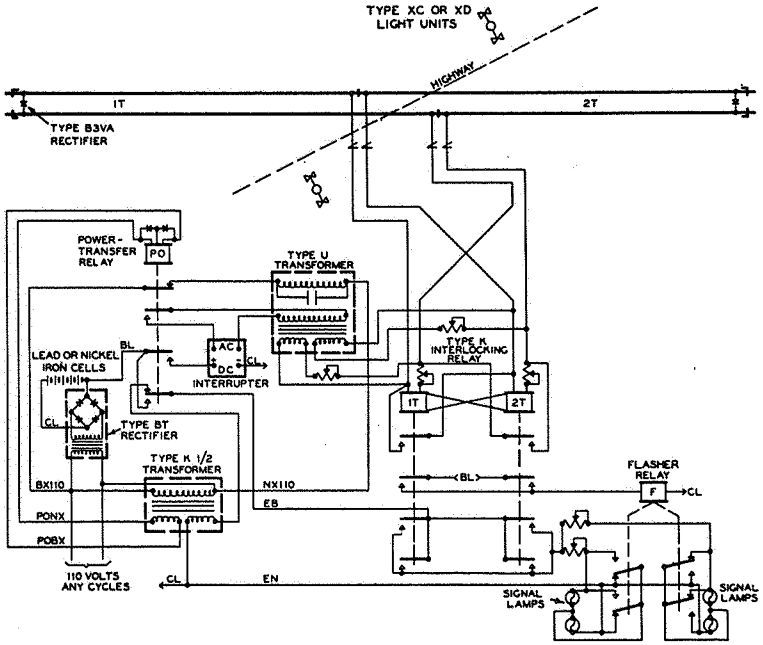
TYPE XC OR XD LIGHT UNITS
HIGHWAY
1T
2T
TYPE B3VA RECTIFIER
POWER-TRANSFER RELAY
PO
TYPE U TRANSFORMER
LEAD OR NICKEL IRON CELLS
BL
AC
DC
CL
INTERRUPTER
TYPE K INTERLOCKING RELAY
1T
2T
TYPE BT RECTIFIER
TYPE K 1/2 TRANSFORMER
BX110
NX110
EB
PONX
POBX
BL
FLASHER RELAY
F
CL
110 VOLTS ANY CYCLES
CL
EN
SIGNAL LAMPS
SIGNAL LAMPS

Figure 807. Half-wave rectified track circuit control for flashing light signals.

all apparatus that may require maintenance attention. In many locations this can be of great benefit, since the ends of the approach sections may be hard to reach.

Operation of this circuit is similar to that described for Figure 805 except for method of energizing the Type K interlocking relay. Each side of the relay (coils 1T and 2T) is connected to its respective track circuit 1T and 2T in the usual manner. Each side is also connected directly to a separate secondary of the Type U transformer. The Type B3VA rectifiers are, in effect, connected directly across their respective relay coils. One half of each a-c. sine wave thus passes through the relatively low resistance rectifier. The other half of each sine wave, blocked by the valve action of the rectifier, energizes the relay coils. During the half cycle blocked by the rectifier, the current induced by the collapsing coil flux also flows through the rectifier thus tending to keep its half of the relay energized.

A train shunting either rectifier removes its effect from the circuit so that that side of the d-c. relay is fed a.c., and the armature of that side promptly releases.

A storage battery on trickle charge supplies energy for the flasher relay. The lamps are normally fed from a.c., but the power-transfer relay switches them to the storage battery if the a.c. fails, and also energizes an interrupter which energizes a primary of the Type U transformer so that a.c. continues to feed to the tracks.

This circuit features unusually high shunting sensitivity, and it is very economical to install and convenient to maintain. Relay cases, line drops, batteries, etc., are not required at the far ends of the track circuits.

At locations where battery standby is not required, the power-transfer relay, interrupter, battery charging rectifier, and battery are omitted. A small rectifier is used to operate the d-c. flasher relay.

Primary-Battery Control Circuit

At locations where a supply of alternating current is not available and where it is impracticable to furnish such service, highway crossing signals may be energized by a primary battery as shown in Figure 808.

If, at some later date, alternating current is made available at the location, the primary battery may be replaced with a storage battery and a battery-charging rectifier, and a small transformer can be added to supply energy to the lamps. Thus all the original equipment, except the primary battery, can continue in use at the same location.

Timing Considerations

It is commonly accepted that the warning time for a crossing approach should be calculated as 20 seconds for the fastest train. If, therefore, a freight train should drift into the approach section with the intention of stopping to do switching, the operation of the highway signal would be misinforming highway traffic as to what to expect. A few instances of this inclines the public to disregard the warning signal. This fault can be greatly reduced by dividing the track circuit so that the entering section will actuate a time relay which at the expiration of a specified time will cut out one approach track and thus lessen traffic delay. The restart track section should be long enough to give the required 20 seconds for a slower train movement. At high speed, the timer would not pick up before the train entered the restart section, and the warning would therefore be continuous. The same principle is used for selective speed control, where train speeds vary substantially. Thus the faster trains get through the timing section before the time element relay can act to reduce the approach warning distance to that required for slower trains.

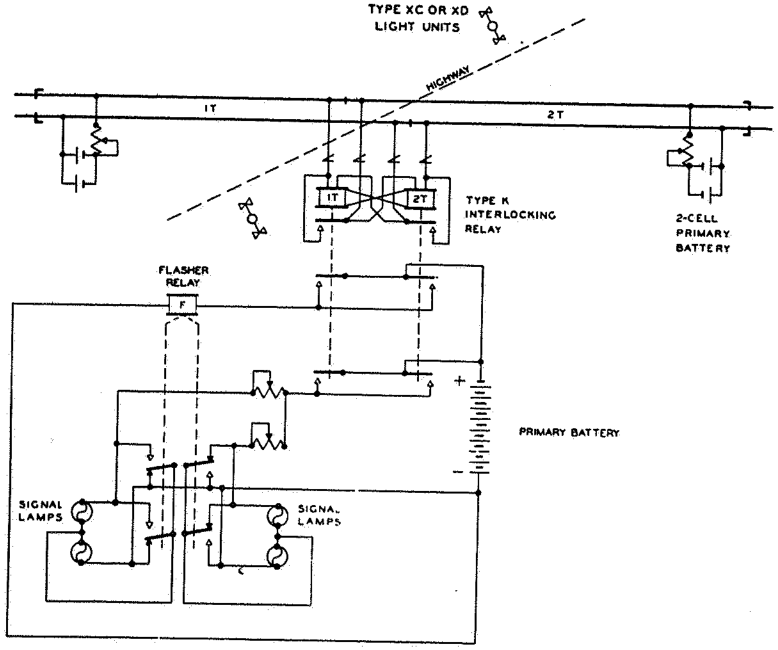

Figure 808. Flashing light control circuit for primary battery operation.

Where the distance from the most remote signal to the clearance of the farthest track on which trains operate at medium or higher speed, as measured parallel to the center line of the highway, is 35 feet or less, the signals shall operate for not less than 20 seconds before the arrival of any train on such track. Where this distance is more than 35 feet, the minimum time should be increased by one second for each additional 5 feet.

HIGHWAY CROSSING GATES

At crossings where train and traffic density warrant, the installation of automatic gates, Figure 809, in combination with flashing lights is advisable. A favored practice is to install half gates, the gate on each side of the track extending only to the middle of the street and blocking approaching traffic so that a vehicle caught between the gates may get in the clear around the end. Statistics show that automatic gates in combination with flashing lights are the most efficient crossing protection system short of actual grade separation.

The track controls, manual controls, and test boxes are the same for gate installations as for flashing lights, but the local circuits differ. As highway gates are normally energized, the

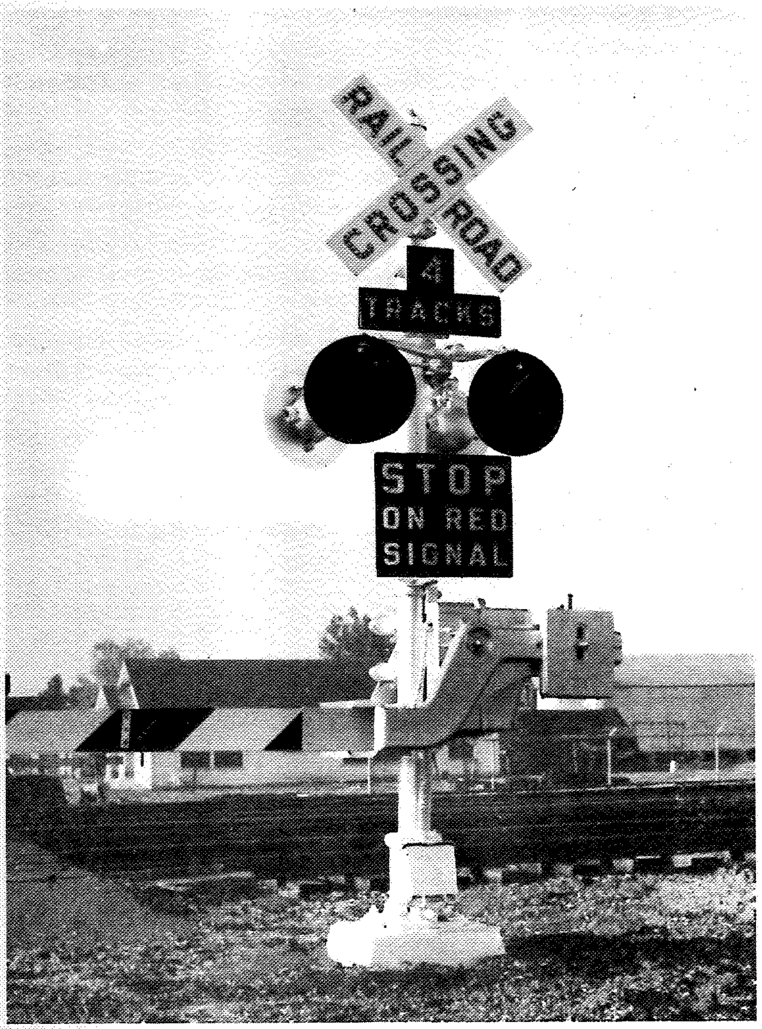

Figure 809. Automatic electric crossing gate.

control circuit must be through closed front contacts, and interlocking relay contacts must be made in the interlocked position. Referring to Figure 804, if this relay were designed for a gate control circuit, the right-hand half of the interlocking relay would have its front contacts closed in the last two views—even with the armature "on the hook."

As gates are considered an adjunct to crossing signals, it is a requisite that the lights and bells shall operate three to five seconds before the gates start to descend. The total descent time including the preliminary time lag is about fifteen seconds, which means that the gate is entirely down only about five seconds before the train arrives. It will be seen that the gates act only as a positive physical barrier, while the lights and bells serve their usual purpose of sufficient advance warning.

When the gate is within 10° of horizontal, the bell is automatically cut out, but the lights continue to flash until the clearing gate is within 5° of vertical.

The only means of hand operation of the gates is to push them by hand, secure them with a hook or wire, and pull an emergency switch to pick up the relay which cuts out the lights and bells until repairs are made.

Indicator lights, if required, would be controlled through mechanism contacts 0° to 3° in series through all gates to indicate gates down to trainmen or remote operator. Lights could also be provided to indicate gates up by breaking another light circuit through contacts from 87° to 90°. It is sometimes required that an operator in a central tower control a number of gates at several streets during certain hours and then switch them to automatic operation at other times. Such controls and indicators are sometimes included on a regular all-relay interlocking control panel.

The G-R-S Type **B** gate mechanism, Figure 810, has self-contained bearings, and the mechanism is centered on the pole.

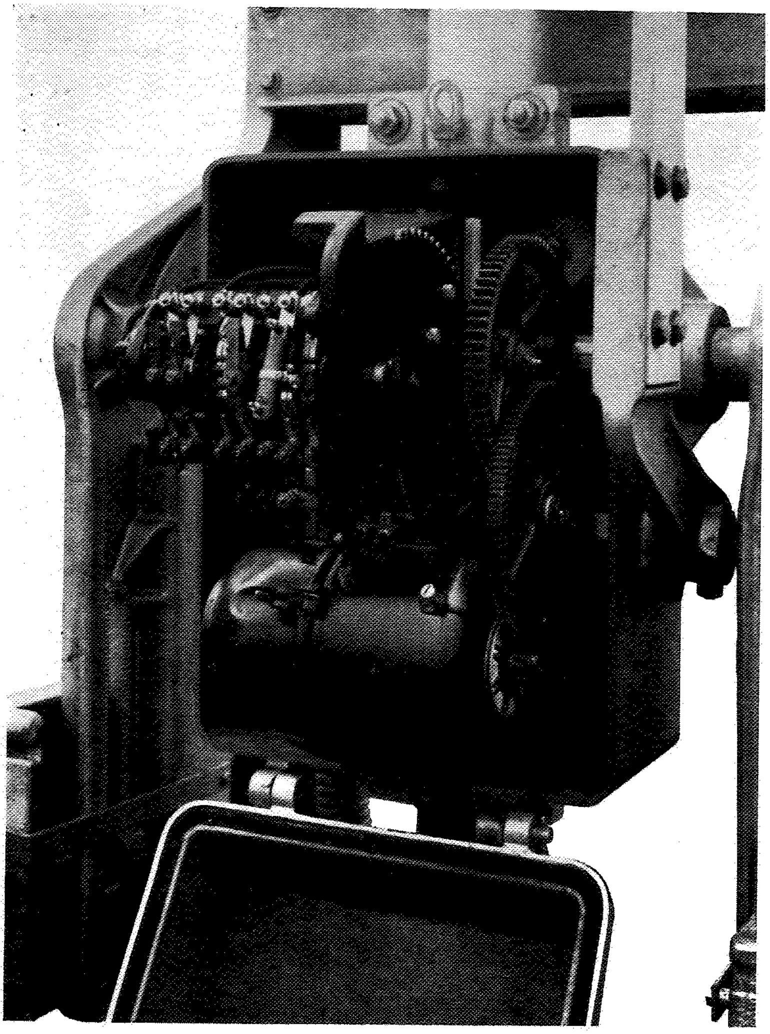

Figure 810. G-R-S Type B crossing gate mechanism.

It has a d-c. motor, which operates on 14 to 16 volts for all nominal length gates, and a circuit breaker or controller with 14 contact spaces, any of which can be varied as to angle of make or break independently of the others.

The motor drives the gate to the clear position, and a hold-clear device including coils, armature, ratchet and ratchet wheel, holds it in the clear position until the energy to the holding coils is removed. This allows the ratchet to drop out of mesh with the ratchet wheel and the contacts on the hold-clear device to drop. With these contacts dropped, a circuit is made through the down field windings in the motor, and the gate is driven down to 45°. At 45° a contact on the controller opens and removes the energy from the motor, and the gates lower to the horizontal position by gravity. A "snub" circuit, using the motor as a generator, controls the final descent so that the gate arms come to a gentle stop. Some railroads, however, prefer a complete gravity gate, and the wiring is changed slightly to permit this action.

INTERLOCKING

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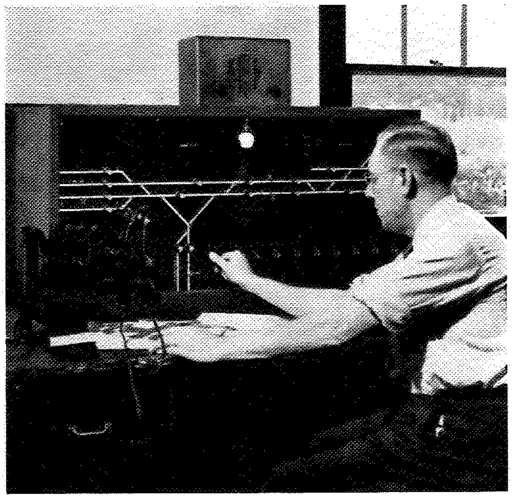


Figure 901. A typical Type B relay interlocking control machine for use on a table or desk.

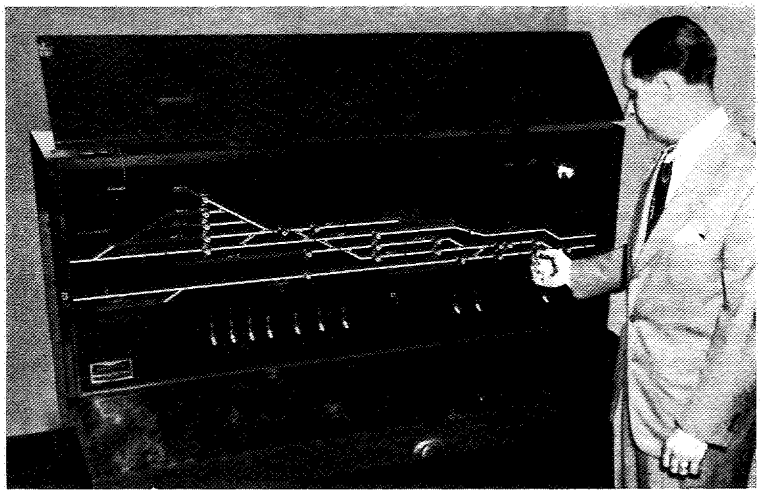


Figure 902. A typical Type C relay interlocking control machine, floor type.

RELAY INTERLOCKING

INTRODUCTION

Interlocking is employed to facilitate and safeguard the movement of trains at terminals, junction points, railroad grade crossings, and drawbridges. It is defined as: "An arrangement of signals and signal appliances so interconnected that their movements must succeed each other in proper sequence and for which interlocking rules are in effect. It may be operated manually or automatically."

Interlocking may be accomplished by mechanical, electro-mechanical, electric, automatic, or relay methods. The relay method only will be discussed here, as it is the modern system.

CONTROL MACHINES

G-R-S control machines for relay interlocking are made in two types: the Type B, Figure 901, which rests on a table or desk, or the Type C, Figure 902, which stands on the floor.

SWITCH MACHINES

G-R-S Models 5C or D switch machines are commonly used in relay interlocking. Model 5D, Figure 903, has a dual-control arrangement so that trainmen can operate the switch by hand, such as when switching at a remote location. Both models may be relay controlled and use relayed battery indication.

The essential parts of these machines are motor, gearing, operating and locking members, pole-changer, point detector of the over-and-locked type, and lock and detector rod combinations to fit any specified requirements. A complete description of Models 5A, B, C, and D switch machines may be found in G-R-S Handbook 24. For the purpose of understanding the circuits to follow later, it will be necessary here to deal with the electrical control of the switch machine.

The switch machine controller, Figure 904, usually mounted inside the machine, consists of an overload relay and two

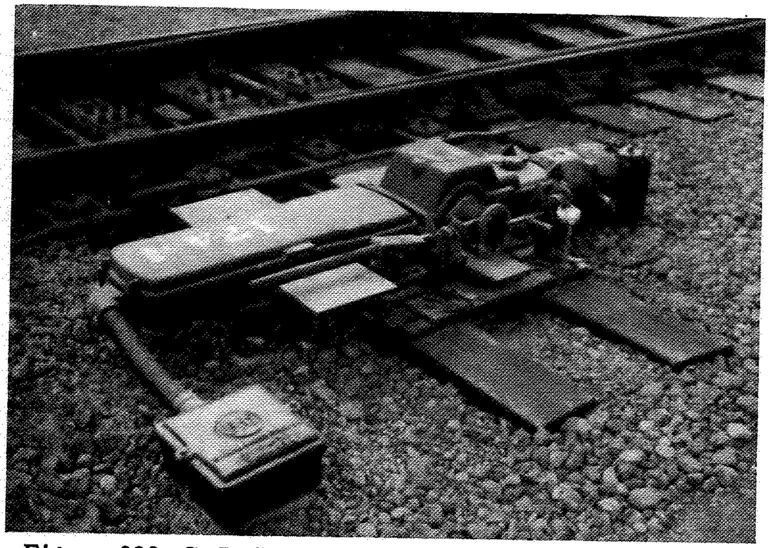


Figure 903. G-R-S Model 5D electric switch machine.

biased-neutral contactors. The magnetic structure of each biased-neutral contactor is such that it will operate only when current flows through its windings in a specified direction. This feature provides for two-wire polarized control of the switch machine, either over line or by means of local control relays. Operating energy to the switch machine is controlled through the heavy-duty contacts of the biased-neutral contactors.

The overload relay acts to deenergize the contactors if the motor draws excessive current, for example, if an obstruction jams the switch. Reversing the controller energy automatically resets the overload relay to permit operating the machine in the opposite direction.

A typical wiring diagram for a Model 5C or D switch machine with a biased-neutral controller is shown in Figure 905. Operation is as follows:

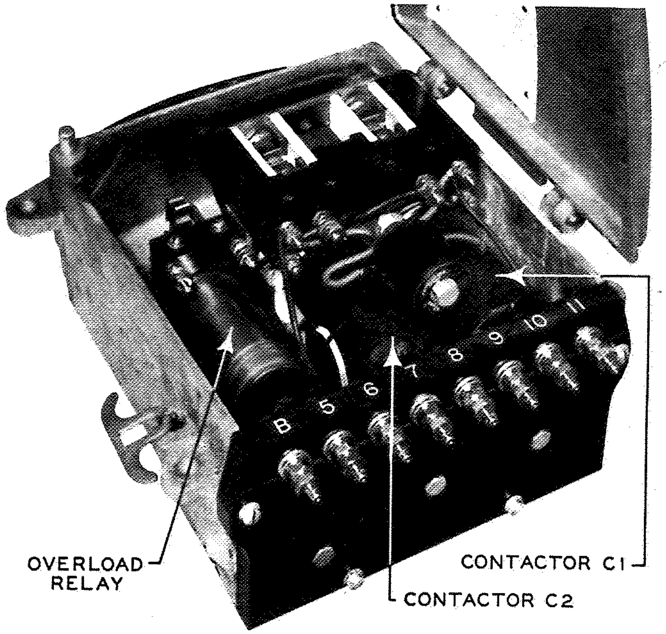


Figure 904. Biased-neutral controller.

1. When the operator calls for the machine to operate to the left (as observed from point-detector end), NWR will be energized positively. This will cause contactor C2 to close its front contact and, through the centering device, to close the back contact of C1. This will complete the motor circuit and operate the machine to the left. As the machine unlocks, point-detector contacts 7D-2C will close. When the machine completes its stroke, point-detector contacts 1C-8D will open, deenergizing contactor C2 and opening the motor circuit.

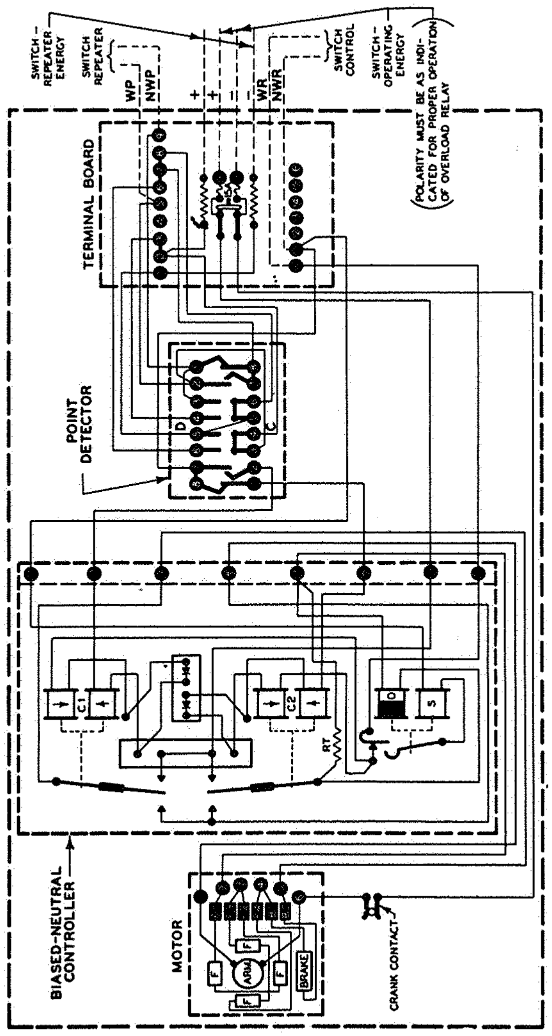

SWITCH-REPEATER ENERGY
SWITCH REPEATER
WP
NWP
+
-
WR
NWR
SWITCH CONTROL
SWITCH-OPERATING ENERGY
POLARITY MUST BE AS INDICATED FOR PROPER OPERATION OF OVERLOAD RELAY
TERMINAL BOARD
POINT DETECTOR
D
C
C1
C2
RT
O
S
BIASED-NEUTRAL CONTROLLER
MOTOR
ARM
F
BRAKE
CRANK CONTACT

Figure 905. Typical wiring diagram for Model 5C switch machine with biased-neutral controller.

2. When the operator calls for the machine to operate to the right, NWR will be energized negatively. This will cause contactor C1 to close its front contact (contacts 7D-2C were closed and contacts 1C-8D were opened during operation of machine to the left). C2 back is closed by the centering device, and current now flows through the motor in a direction to operate the machine to the right. As the machine unlocks, contacts 1C-8D close. When the machine completes its stroke, contacts 7D-2C open, de-energizing C1 and opening the motor circuit.

Thus, as explained above, the point-detector contacts operate to remove current from the switch machine motor at the end of its stroke. As their name indicates, they also detect the position of the switch points, through the point-detector rods. They are also operated by the lock rods to detect whether the switch is properly locked. As shown in Figure 905, they control energy in the switch repeater circuit. WP is positive and NWP is negative. When the switch machine unlocks itself, wires WP and NWP are connected to shunt the circuit. When the machine is fully over and locked in its reverse position, WP is negative and NWP is positive. As will be explained later, these contacts are used to control vital switch repeater relays.

The table in Figure 906 shows how the point-detector contacts are positioned as the switch machine unlocks, operates to its new position, and locks up again.

SWITCH POSITION	CONTACTS							
	8D-1C	7D-2C	6D-5D	3C-4C	4D-3D	5C-6C	2D-7C	1D-8C
Normal	closed	open	open	closed	open	closed	open	closed
Unlocked	closed	closed	open	open	open	open	closed	closed
Reverse	open	closed	closed	open	closed	open	closed	open

Figure 906. Positions of point-detector contacts in the switch machine.

METHODS OF CONTROL

All-relay interlocking systems are controlled by either direct wire or code control, but regardless of the system or method of control, the same principles govern and the same general pattern is followed in the design of the safety circuits surrounding the functions at the field location. In fact, it is difficult to determine the type of system or control by an examination of the field circuits beyond the communication portions thereof.

Figure 907 illustrates diagrammatically the interrelation between the various systems. It is intended to emphasize the importance of a thorough understanding of the relay interlocking principles and circuiting surrounding the wayside functions, as these are common to the various systems. It will be noted from Figure 907 that starting from a control machine of the individual lever (IL) type, we can proceed through the control office indication and control circuits via direct wire to the field functions or through office indication and control circuits via direct wire to field indication and control circuits to the field functions or through control office code relays via two line wires to field code relays—ending in each case at the relay interlocking of the field functions. Likewise, starting from an entrance-exit (NX) type machine and proceeding through the network circuits one can then, by any one of the three before-mentioned communication means, again arrive at the same relay interlocking of the field functions.

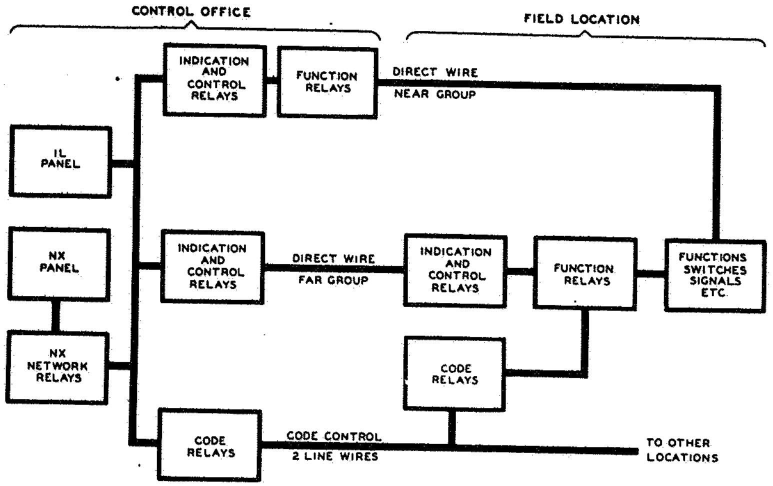

CONTROL OFFICE
FIELD LOCATION
IL PANEL
NX PANEL
NX NETWORK RELAYS
INDICATION AND CONTROL RELAYS
FUNCTION RELAYS
DIRECT WIRE
NEAR GROUP
INDICATION AND CONTROL RELAYS
DIRECT WIRE
FAR GROUP
INDICATION AND CONTROL RELAYS
FUNCTION RELAYS
FUNCTIONS SWITCHES SIGNALS ETC.
CODE RELAYS
CODE RELAYS
CODE CONTROL
2 LINE WIRES
TO OTHER LOCATIONS

Figure 907. Interrelation of systems.

Controls and Indications

When a control machine operator sets up a route in an interlocking, he turns a knob or manipulates levers to send out controls to operate a switch machine, signal or other devices in the interlocking plant. When the device has operated to the position called for, an indication is transmitted back to the control machine to tell the operator that the device has responded properly to his control.

Direct Wire Near Group Control

A near group, Figure 908, is controlled over direct wires from the control machine to the control relays. This system requires a relatively large number of line wires. When the distance between the control machine and the control relays

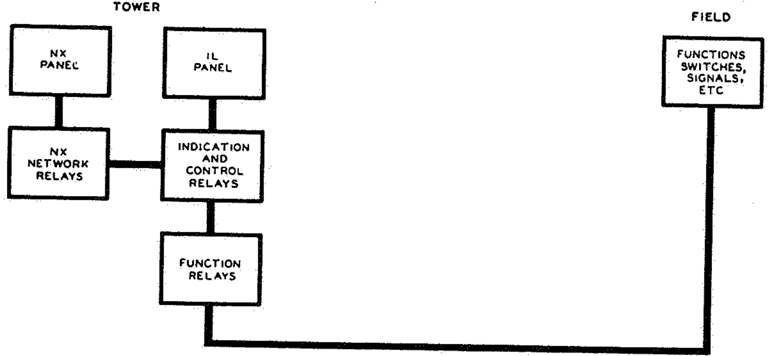
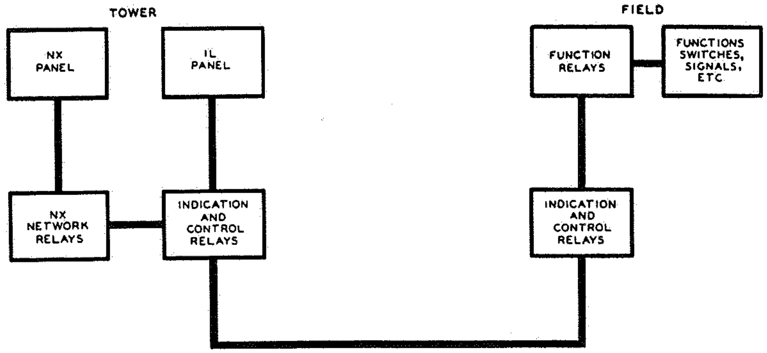

TOWER
FIELD
NX PANEL
IL PANEL
NX NETWORK RELAYS
INDICATION AND CONTROL RELAYS
FUNCTION RELAYS
FUNCTIONS SWITCHES, SIGNALS, ETC

Figure 908. Direct wire near group control.

becomes great enough, it is no longer economical to use direct wire control.

Direct Wire Remote Group Control

With remote group direct wire control, Figure 909, the controls and indications are carried through relays in the tower to relays in the wayside case. These relays in turn control relays which operate the switches and signals. Many of these controls and indications run over the same line wires. This method of control has its limitations, again from the cost of line wire, as the distance from the control machine to the field location increases.



TOWER
NX PANEL
IL PANEL
NX NETWORK RELAYS
INDICATION AND CONTROL RELAYS
FIELD
FUNCTION RELAYS
FUNCTIONS SWITCHES, SIGNALS, ETC
INDICATION AND CONTROL RELAYS

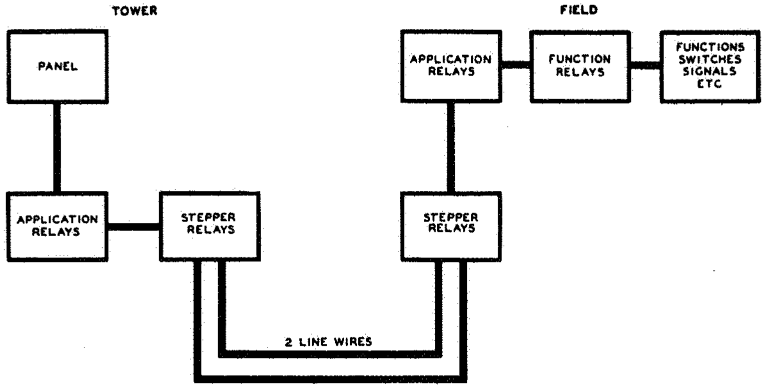
Figure 909. Direct wire remote group control.

Coded Remote Control

Coded systems for transmission of controls and indications are economical of line wire. These systems, through the use of coding relays, send out controls and receive indications on two, or sometimes three, line wires.

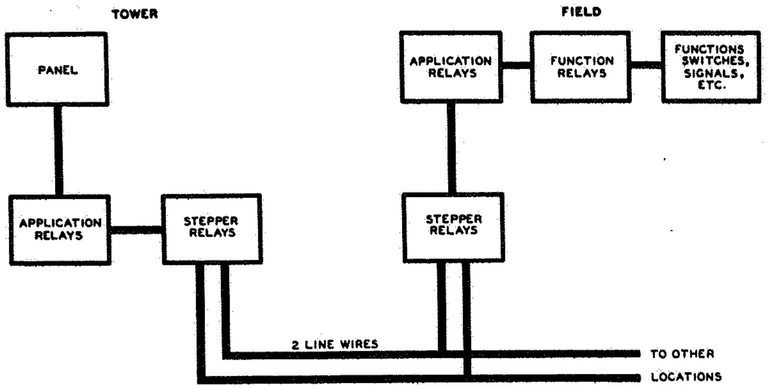
G-R-S Syncrostep, Figure 910, is used for the control of single remote locations (see page 954 for a detailed description of Syncrostep). Other coded systems, such as the G-R-S Type K, Figure 911, are ideal for handling multiple remote field locations (see the section on centralized traffic control).

G-R-S Quikode is a high-speed multiplex coded control system for the control of complex remote interlockings, singly or in multiple.



TOWER
PANEL
APPLICATION RELAYS
STEPPER RELAYS
2 LINE WIRES
FIELD
APPLICATION RELAYS
FUNCTION RELAYS
FUNCTIONS SWITCHES SIGNALS ETC
STEPPER RELAYS

Figure 910. Syncrostep coded remote control.



TOWER
PANEL
APPLICATION RELAYS
STEPPER RELAYS
2 LINE WIRES
FIELD
APPLICATION RELAYS
FUNCTION RELAYS
FUNCTIONS SWITCHES, SIGNALS, ETC.
STEPPER RELAYS
TO OTHER LOCATIONS

Figure 911. Type K coded remote control.

BASIC CIRCUITS

An explanation of direct wire, near group control of a relay interlocking, controlled from an individual lever (IL) type of control panel, is presented in the circuits on the following pages. A layout consisting of a single power-operated turnout with a full complement of signals has been selected.

A TYPICAL CONTROL PANEL

The arrangement of the control panel is shown in Figure 912. The track diagram in the upper portion of the panel represents the track layout (shown in more detail above the panel), which consists of the junction of a non-signaled branch line with a single-track main line equipped with a system of absolute permissive block signaling. In accordance with interlocking practice, signals 1L are located at the clearance point between the main and branch lines, and signal 1R is located in advance of the switch points. The function of these signals is to govern train movements in accordance with the route set up and the condition of the block ahead.

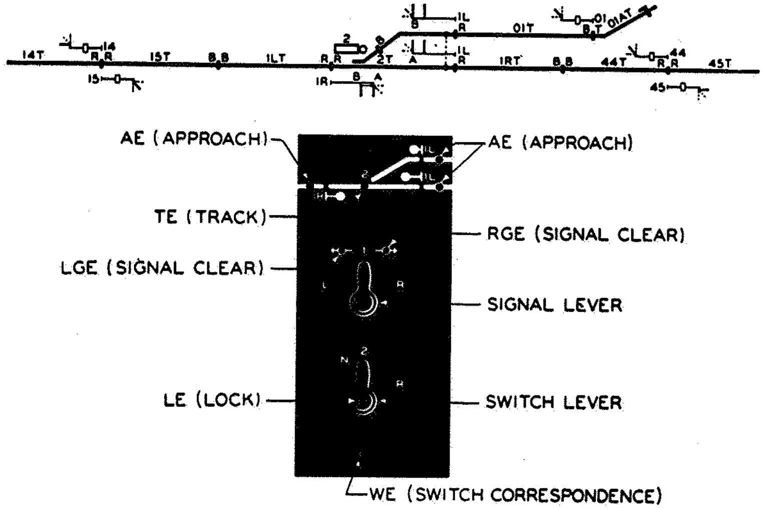


Figure 912. Relay interlocking control panel and track layout.

Home signals 1L and 1R have two arms each, that is there are two separate Type SA signals mounted on each signal mast. Signal 1LA on the main line governs traffic to the left over the switch normal. Signal 1LB on the branch line governs traffic to the left over the switch reverse. Signal 1RA, top arm, governs traffic to the right over the switch normal, and signal 1RB, bottom arm, governs traffic to the right over the switch reverse onto the non-signaled branch line. Single arm automatic signals 15 and 44 act as main-line approach signals to the plant, and signal 01 as the approach signal from the branch line. The home signals normally display red (stop) aspects, and the approach signals display yellow (approach) aspects.

Three approach lights AE on the panel indicate when their respective approaches are occupied by a train (a single-stroke gong or other audible signal is also provided to indicate that a train has arrived on the approach). Track light TE indicates track circuit 2T (at the switch) is occupied.

Switch lever 2 has two positions, normal (N) and reverse (R). This lever is used to control the switch machine. When in the vertical or normal (N) position, it calls for the switch machine to line up a route straight through on the main line. When in the horizontal or reverse (R) position, it calls for the switch machine to line up a route for the branch line. Switch lever contacts NC (Figure 914) are closed from normal (N) to center position (C). Switch lever contacts RC are closed from reverse (R) to center (C). Contacts N and R are closed only when the lever is in the normal or reverse position.

Lock light LE, located in the barrel of the switch lever, indicates the switch is locked and out of the operator's control.

Correspondence light **WE**, located below the switch lever, indicates when the switch machine is not in correspondence with the switch lever.

Signal lever 1 has three positions, right, left and stop. When positioned to the left (L), it initiates a control to clear either signal 1LA or 1LB for traffic movement to the left. When positioned to the right (R), it initiates a control to clear signal 1RA or 1RB for traffic movement to the right. In the vertical position, all signals are at stop. Signal-clear lights **RGE** and **LGE** indicate when signals are cleared for a traffic movement to the right or left.

CIRCUIT SYMBOLS

The relays, signal mechanisms, and switch machine referred to in the following circuit description all operate on direct current supplied by battery. The diagram in Figure 913 shows the symbols used to identify the positive (BL), negative (NL), and common (CL) of split battery. Split battery provides the pole changing feature for the operation of the magnetic-stick relays, which change position only when the energy supply is reversed.

Indication and signal lamps are usually supplied energy from the secondary of a transformer. The diagram **in** Figure 913 shows the symbols to identify the positive (EB) and the negative (EN) taps on a transformer secondary.

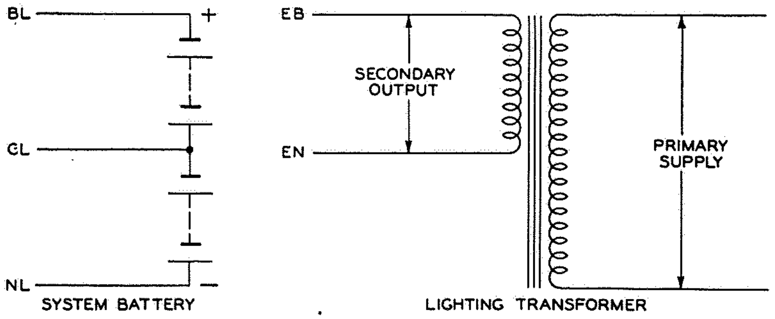

BL
+
CL
NL
−
SYSTEM BATTERY
EB
SECONDARY OUTPUT
EN
PRIMARY SUPPLY
LIGHTING TRANSFORMER

Figure 913. Power supply symbols.

The heavy lines in the following circuits indicate which part of the circuit is being discussed, the arrows indicate the direction of current flow.

APPROACH INDICATION

When a train approaches the interlocking plant, the track relays drop and in turn drop approach relay **AR**, Figure 914, closing its back contact to complete the circuit from **EB** through lamp **AE** to **EN**.

Detection of a train on the approach is usually arranged so that the control machine operator has time to clear the home and, in turn, the approach signal before the engineer is forced to make a brake application.

SWITCH CONTROL

Lock indication relay **LKR**, slow release to bridge the cross-

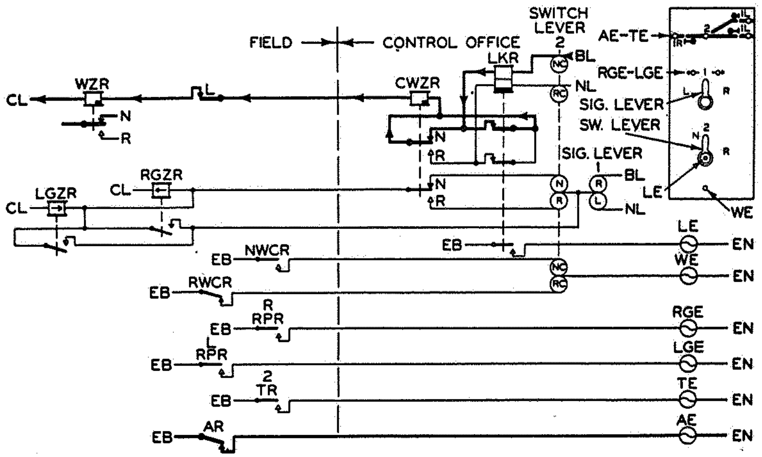

FIELD
CONTROL OFFICE
SWITCH LEVER 2
AE-TE
RGE-LGE
SIG. LEVER
SW. LEVER
SIG. LEVER
CL
WZR
N
R
L
CWZR
LKR
BL
NL
RGZR
LGZR
LE
WE
EB
NWCR
RWCR
RPR
TR
AR
EN
RGE
LGE
TE
AE

Figure 914. Relay interlocking control and indication circuits, switch control.

over of correspondence relay **CWZR**, indicates when it is possible to operate the switch machine. Magnetic-stick relay **CWZR** checks that the switch lever, if it is to be effective in controlling the switch, must be in position to correspond with the position of the switch machine, and agreeing with the position of magnetic-stick switch control relay **WZR**.

Figure 914 shows the circuit in heavy lines which is energized to move the switch to its normal position for a main-line move. With the switch lever in the **N** position, positive of split battery, **BL**, is applied to the **LKR**, **CWZR**, and **WZR** relays in series to common, **CL**, of the split battery. A front contact of lock relay **L** is inserted in the circuit to prevent changing the position of the **WZR** relay when the locking in the field is in effect, when, for example, a signal has been cleared.

To reverse a switch, **Figure 915**, the operator moves the switch lever to the **R** position. Negative **NL** of split battery applied through the **RC** contact on the lever drops magnetic-stick relays **CWZR** and **WZR** to call for the switch machine to operate to the reverse position for a move onto the branch line.

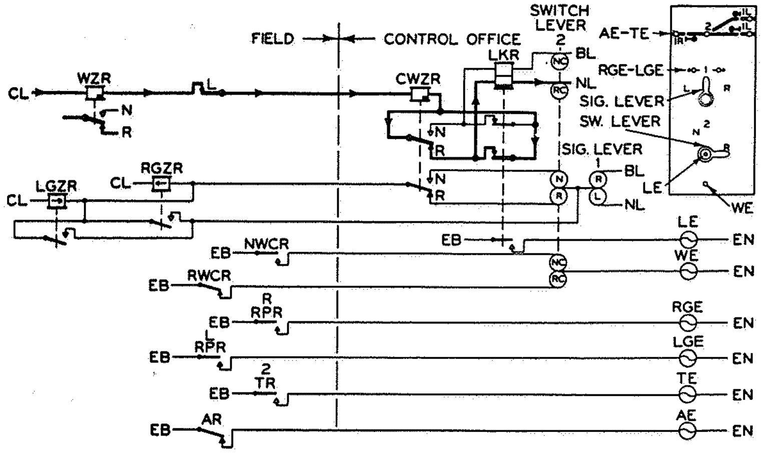

FIELD
CONTROL OFFICE
SWITCH LEVER 2
AE-TE
LKR
BL
RGE-LGE
NL
SIG. LEVER
SW. LEVER
SIG. LEVER 1
CL
WZR
L
N
R
CWZR
RGZR
LGZR
NWCR
RWCR
RPR
TR
AR
EB
NC
RC
LE
WE
RGE
LGE
TE
AE
EN

Figure 915. Relay interlocking control and indication circuits, switch reverse.

If the operator leaves the switch lever in the center position, Figure 916, both sides of split battery, **NL** and **BL**, are applied through lever contacts **NC** and **RC** to hold **LKR** relay energized. Lock indication light **LE**, controlled over a back contact of the **LKR** relay, cannot be lit. Switch-out-of correspondence light **WE** will be lit, indicating that the position of the switch lever does not correspond with the position of the switch machine. The **WE** lamp is controlled over a back contact of either **NWCR** or **RWCR**, the normal or reverse switch correspondence relays, respectively, and switch lever contacts normal or reverse.

CLEARING A SIGNAL

Signal control relays **LGZR** and **RGZR**, for clearing signals to the left or right respectively, are biased-neutral relays. They will pick up only when voltage of the proper polarity is applied

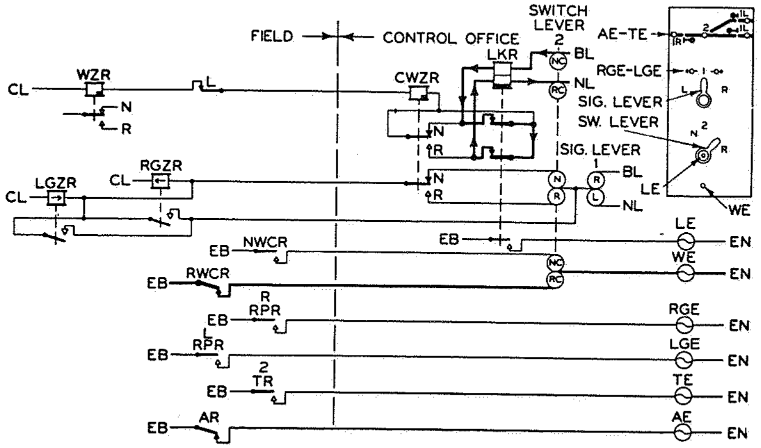

FIELD
CONTROL OFFICE
SWITCH LEVER 2
AE-TE
LKR
BL
RGE-LGE
NL
SIG. LEVER
SW. LEVER
SIG. LEVER 1
CL
WZR
L
N
R
CWZR
RGZR
LGZR
NWCR
RWCR
RPR
TR
AR
EB
NC
RC
LE
WE
RGE
LGE
TE
AE
EN

Figure 916. Relay interlocking control and indication circuits, switch lever in center position.

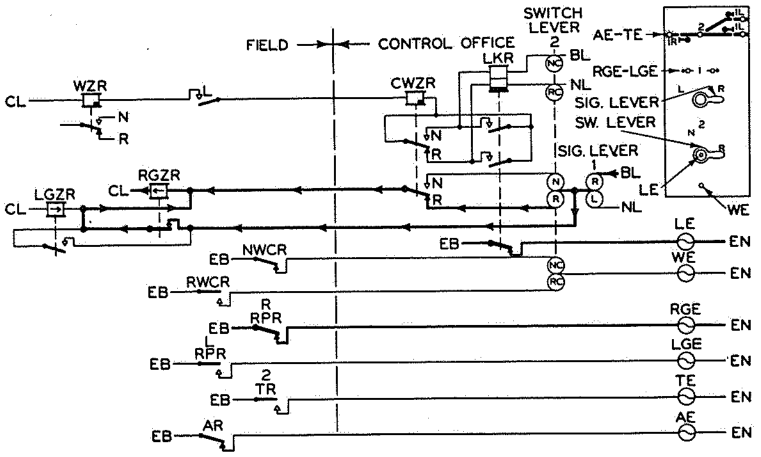

FIELD
CONTROL OFFICE
SWITCH LEVER 2
AE-TE
LKR
CWZR
BL
RGE-LGE
NL
SIG. LEVER
SW. LEVER
SIG. LEVER 1
WZR
CL
N
R
L
RGZR
LGZR
LE
WE
NWCR
RWCR
RPR
TR
AR
EB
RGE
LGE
TE
AE
EN

Figure 917. Relay interlocking control and indication circuits, signal 1R cleared.

to their windings. **LGZR** and **RGZR** repeat the left or right position of the signal lever only if the switch lever is in correspondence with the **CWZR** relay. This check of correspondence between the switch lever and relay **CWZR**, known as the route-check feature, insures that a signal cannot be cleared over an unintended route if the **CWZR** relay, and consequently the **WZR** relay, since they operate in series, do not follow the position of the switch lever.

The circuit in Figure 917 shows the condition that exists when signal lever 1 has been positioned to the right to clear signal 1R over the switch reverse for a branch-line move. Positive **BL** of split battery is applied through **R** contact of the signal lever, **R** contact of the switch lever and back contact **R** of **CWZR** to check the switch lever in the reverse position. Relay **RGZR** picks up and is then stuck up through a circuit which bypasses the switch lever and **CWZR** contacts, thus preventing putting signal 1R to stop by unintentional operation of the switch lever.

When signal 1R has cleared, right red signal repeater relay **RRPR** drops closing its back contact, Figure 917, to apply **EB** to right signal clear indication lamp **RGE**. Lock-indication lamp **LE**, controlled over a back contact on **LKR**, is lighted to indicate that the switch is over and locked.

OS INDICATION

When a train has accepted the clear signal, it moves into the interlocking plant. When it has just passed the home signal it arrives on the OS track, dropping track relay 2TR, Figure 918. Lamp energy is thus applied to light lamp **TE** indicating that a train is on the switch track circuit.

When the train passes the home signal, the signal goes to red and right red signal repeater relay **RRPR** picks up, opening the circuit to lamp **RGE**.

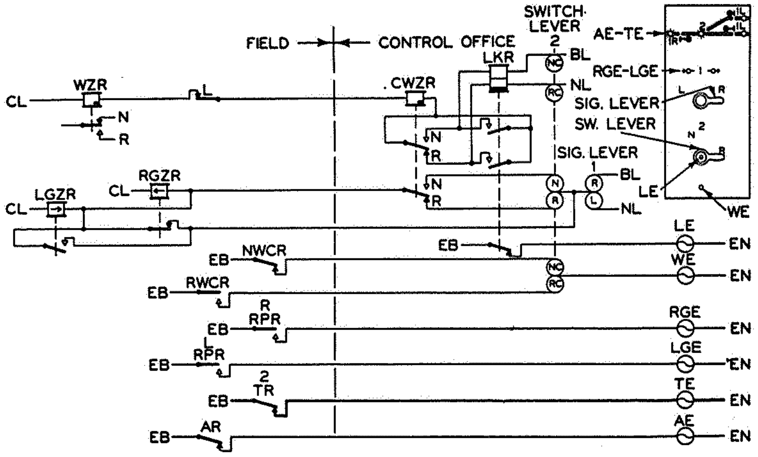

FIELD
CONTROL OFFICE
SWITCH LEVER 2
AE-TE
LKR
CWZR
BL
RGE-LGE
NL
SIG. LEVER
SW. LEVER
SIG. LEVER 1
WZR
CL
N
R
L
RGZR
LGZR
LE
WE
NWCR
RWCR
RPR
TR
AR
EB
RGE
LGE
TE
AE
EN

Figure 918. Relay interlocking control and indication circuits, train passing signal 1R.

PRECONDITIONING—ITS PREVENTION

Preconditioning a route through the plant, that is, moving the switch lever in position for a second train while the first train is occupying a conflicting route, is prevented by the circuit arrangement shown in Figure 919. With preconditioning, the levers on the control machine can be lined up for a following move, so that when the first train clears the home signal the new route is immediately set up.

To prevent preconditioning of the switch control when the locking in the field is in effect, the circuit is organized in such a manner that if the position of the switch lever is changed when the **LKR** relay is deenergized, due to the **L** relay being down, the **WZR** and **CWZR** relays will not assume the new position called for by the switch lever when locking becomes released and the **L** relay picks up to close the circuit in the field.

Referring to Figure 919, the **L** relay contact will be open when the signal is clear. This allows **LKR** to close its back contacts. **CWZR**, a magnetic stick relay, remains in its last-operated position. When the train leaves the interlocking, **L** relay picks up, but with the circuit from **BL** through switch lever contact **NC** still open at the contacts on **LKR**, a change in switch machine position cannot be effected. The circuit therefore insures that the switch lever must be returned to the reverse position to correspond with the position of the **CWZR** relay and thus the switch machine. After this correspondence is established and the **LKR** relay picked up, the switch lever can be moved to **N** and the **CWZR** and **WZR** relays will follow.

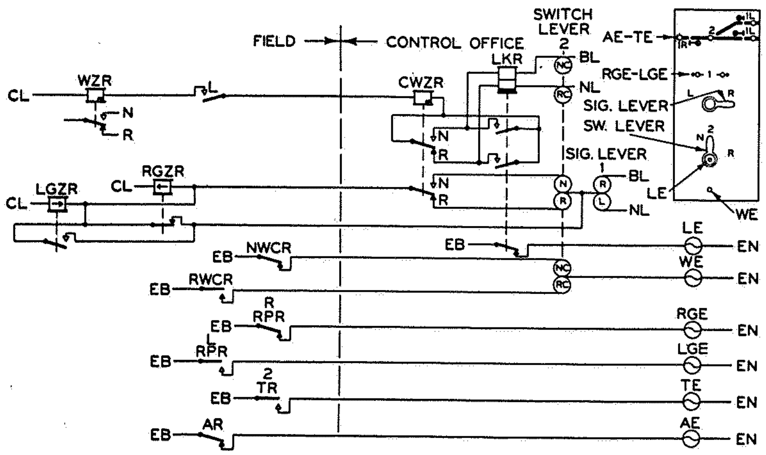


Figure 919. Relay interlocking control and indication circuits, preventing preconditioning.

RELAY INTERLOCKING AND SWITCH CONTROL

Having the **WZR** and **GZR** relays for the control of the switch and signals, the next consideration is to develop a system of relay interlocking that will protect the power switch machine (1) against operation when a home signal is displaying a proceed aspect for a route over it, (2) against operation for a predetermined time after a home signal has been put to stop with a train occupying the approach section and, (3) against operation under a train.

Signal Indication Locking

Signal indication locking is that part of the locking that prevents changing the position of the switch points when a home signal is clear.

Red signal repeater relays **1RRP** and **1LRP**, Figure 920, detect the clearing of a home signal, as they are energized over contacts in the home signals that are closed only when these signals are displaying a stop indication. Battery for the circuits of the **AS** relays is taken over front contacts of the **RP** relays, thus relays **1RAS** or **1LAS** will be deenergized when their respective signals are clear. Front contacts of the **AS** relays are included in the control of lock relay **L**, which, when down, locks the switch by opening the pickup circuit of the **LS** relay.

Approach Locking

Approach locking is that part of the locking that protects against changing the route in advance of a train which has accepted an approach signal displaying a proceed aspect permitting it to approach the plant at a speed too high to be brought to a stop short of a home signal.

Approach relays 1RA, 1LAA and 1LBA, Figure 921, detect the presence of a train on any one of the three approaches to the plant. The circuits of the approach relays are taken over front contacts of the track relays of the section between the home signal and the approach signal as well as the relay for the track circuit in the rear of the approach signal.

The direct pickup of the AS relays is taken over front contacts of the A relays, thus an AS relay will not immediately pick up after a home signal is put to stop if the approach is occupied. It will be noted that relay 1LAS has two approaches in its direct pickup circuit, 1LAA on the main line and 1LBA on the branch line. Contacts of switch-repeater relays NWC and RWC shunt one or the other out of the circuit, depending on the route set up.

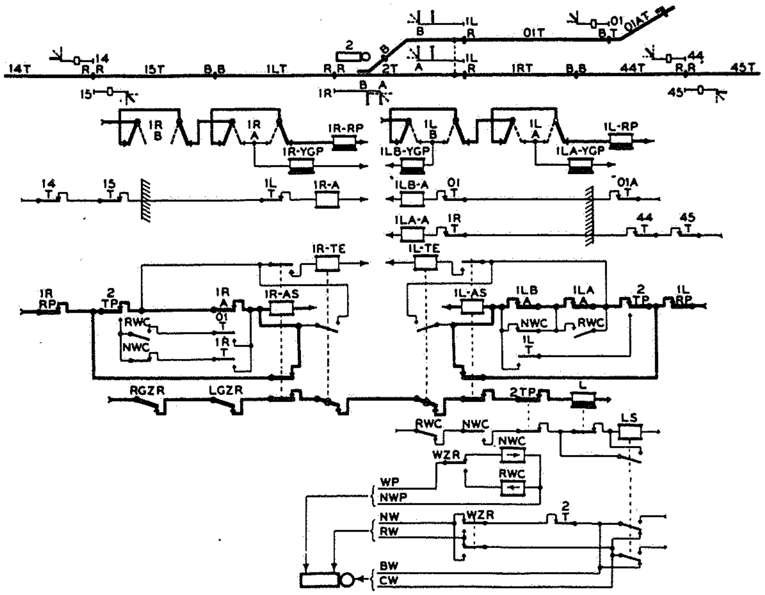

14T
15T
1LT
1RT
01T
44T
45T
2T
IR-RP
IR-YGP
ILB-YGP
ILA-YGP
IL-RP
IR-A
ILB-A
ILA-A
IR-TE
IL-TE
IR-AS
IL-AS
RGZR
LGZR
RWC
NWC
WZR
LS
WP
NWP
NW
RW
BW
CW

Figure 920. Relay interlocking locking and switch control circuits showing signal indication locking.

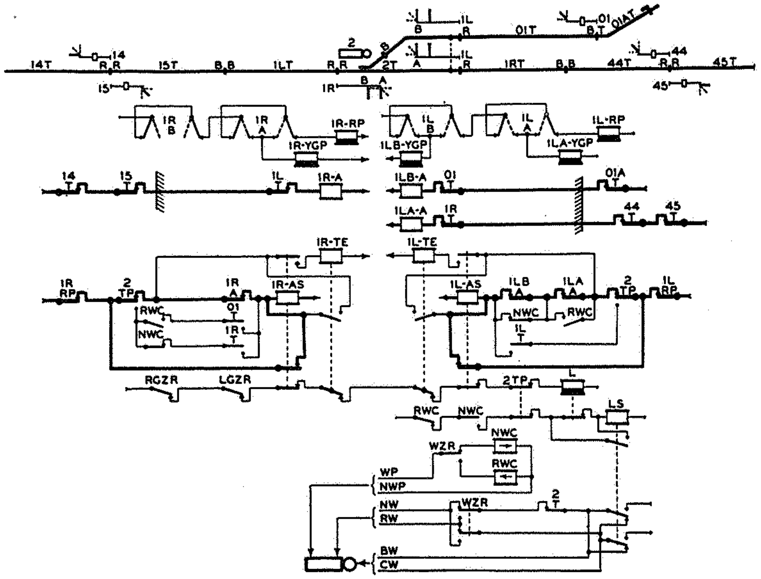

14T
15T
1LT
1RT
01T
44T
45T
2T
IR-RP
IR-YGP
ILB-YGP
ILA-YGP
IL-RP
IR-A
ILB-A
ILA-A
IR-TE
IL-TE
IR-AS
IL-AS
RGZR
LGZR
RWC
NWC
WZR
LS
WP
NWP
NW
RW
BW
CW

Figure 921. Relay interlocking locking and switch control circuits showing approach locking.

Approach Locking, Time Release

When a train is occupying the approach to a signal that is manually put to stop, Figure 922, time-element relay TE will be energized over a back contact of AS. After the time expires for which the TE is set, it will close its front contact to energize the AS relay, Figure 923, and AS back opens circuit to TE.

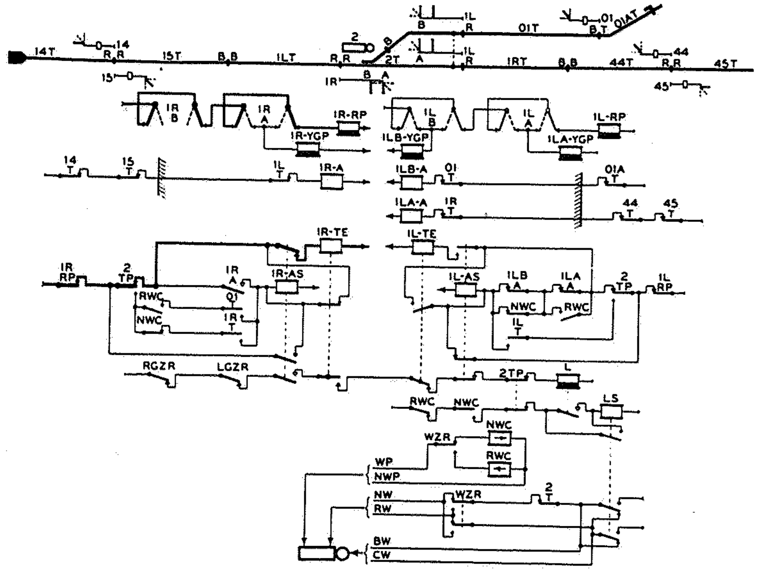

14T
15T
ILT
IRT
OIT
44T
45T
IR-RP
IR-YGP
ILB-YGP
ILA-YGP
IL-RP
IR-A
ILB-A
ILA-A
IR-TE
IL-TE
IR-AS
IL-AS
RWC
NWC
RGZR
LGZR
2TP
L
LS
WZR
WP
NWP
NW
RW
BW
CW

Figure 922. Approach locking circuit shown at instant 1RTE front contact closes.

The Signal Section of the AAR has set forth the following recommendations for setting of time releases:

1. The minimum releasing time should be more than the maximum braking time encountered when a full service application of the brakes is made for the purpose of stopping a train of minimum braking power just before it reaches the home signal.
2. In territory where two-block indication governs, the basis for setting the time releases must be the time required to move the distance between the approach signal and the signal locked, plus 1500 ft. at a speed of 30 miles per hour (44 ft. per second).

Assuming that approach signal 15 is located 9000 ft. in the

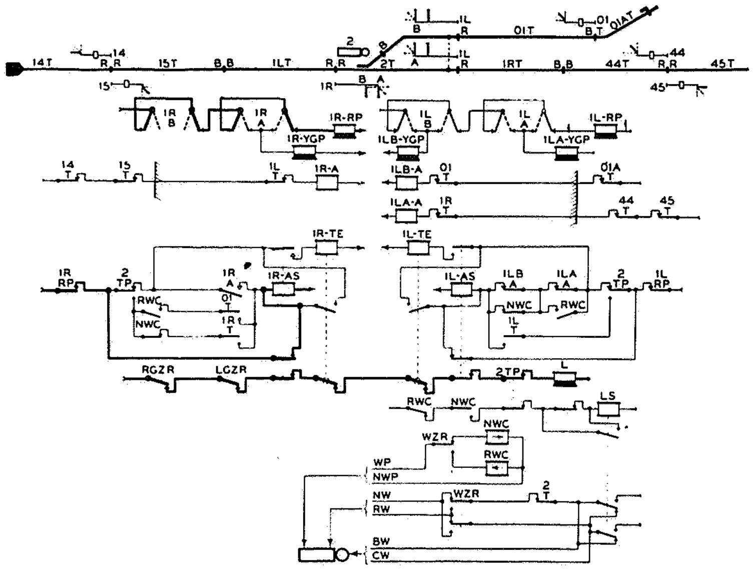

14T
15T
ILT
IRT
OIT
44T
45T
IR-RP
IR-YGP
ILB-YGP
ILA-YGP
IL-RP
IR-A
ILB-A
ILA-A
IR-TE
IL-TE
IR-AS
IL-AS
RWC
NWC
RGZR
LGZR
2TP
L
LS
WZR
WP
NWP
NW
RW
BW
CW

Figure 923. Approach locking circuit shown with 1RAS energized, 1RTE check contact closed.

rear of signal 1R, the time setting for 1RTE would be 9000 ft. plus 1500 ft. or 10,500 ft. divided by 44 ft. per second, equaling 238 seconds or about four minutes.

Where one time release handles two or more approaches, as does 1LTE, the setting must be for the longest time encountered.

To insure that the time-element relays return to normal after each operation, their back-checking contacts are included in the circuit of lock relay L.

Approach Locking, Track Release

To permit the route to be changed for a following train that has entered on to the approach before the first train has cleared the plant, a track release on AS is provided. This circuit, Figure 924, is over a back contact of detector track repeater relay 2TP and a back contact of the track relay for the next track section that the train will enter in the route. This is known as a two-track release. The purpose of the second track in this circuit is to guard against the possibility of energizing the AS relay in the advance of an oncoming train if the detector track should be momentarily dropped, such as might happen if track forces were working on the track and a bar accidentally shunted the track.

It will be noted that there is a difference in the track-releasing portions of the two AS circuits. This is because in the case of 1RAS, the second track in the route may be either 1RT or 01T depending on the route set up, thus these tracks are selected

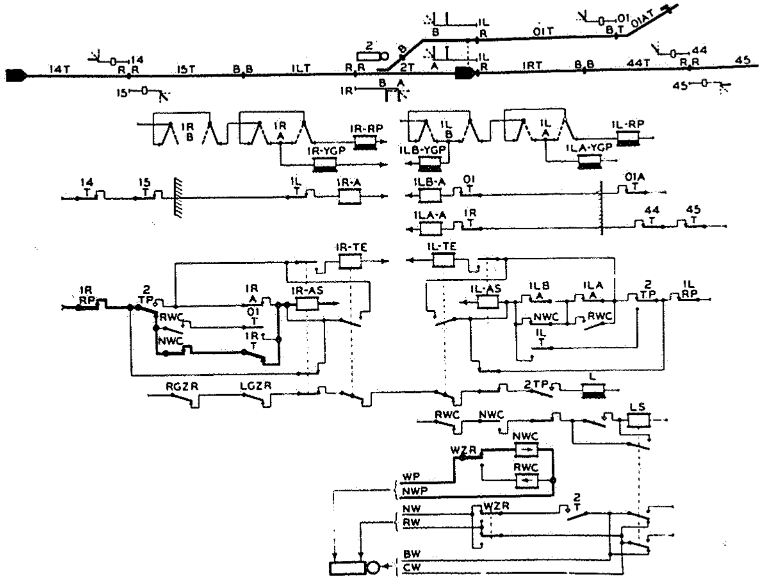


Figure 924. Relay interlocking locking and switch control circuits showing approach locking with track release.

into the circuit over contacts of switch repeater relays **NWC** or **RWC**. In the case of **1LAS**, the second track in the route is always **1LT** so no selection is required.

Detector Locking

Detector locking is that part of the locking, Figure 924, that protects against moving the switch under a train. It is accomplished by including front contacts of detector track repeater relay 2**TP** in the circuits of the **L** and **LS** relays.

Switch Repeater and Correspondence Relays.

Switch-point repeater and correspondence relays **NWC** and **RWC**, Figure 924, are biased-neutral relays. Their control circuit, Figure 924, is pole changed over the point-detector contacts in the switch machine and is energized only when the switch points are locked in the full normal or full reverse position. With the points normal, control wire **WP** is positive with respect to wire **NWP**. This polarity is reversed when the points are in the reverse position. To enforce correspondence between the position of the switch and the route called for, a contact of the **WZR** relay is included in the circuit which, when in the normal position, connects the **NWC** relay and when reverse connects the **RWC** relay.

Switch Control

Switch control is accomplished through a polar controller in the machine, operated over wires **NW** and **RW**, Figure 925. When the position of relay **WZR** is changed from normal to reverse, the **NWC** relay will drop, closing the circuit to pick up relay **LS**, providing relays 2**TP** and **L** are both up. Battery is applied to switch-controller wires **NW** and **RW** over front contacts of relay **LS**. With the **WZR** in the reverse position, wire **NW** will be minus with respect to wire **RW** and thus positions the controller to connect motor wires **BW** and **CW** to operate the points to the reverse position.

When the machine locks up in the reverse position, in cor-

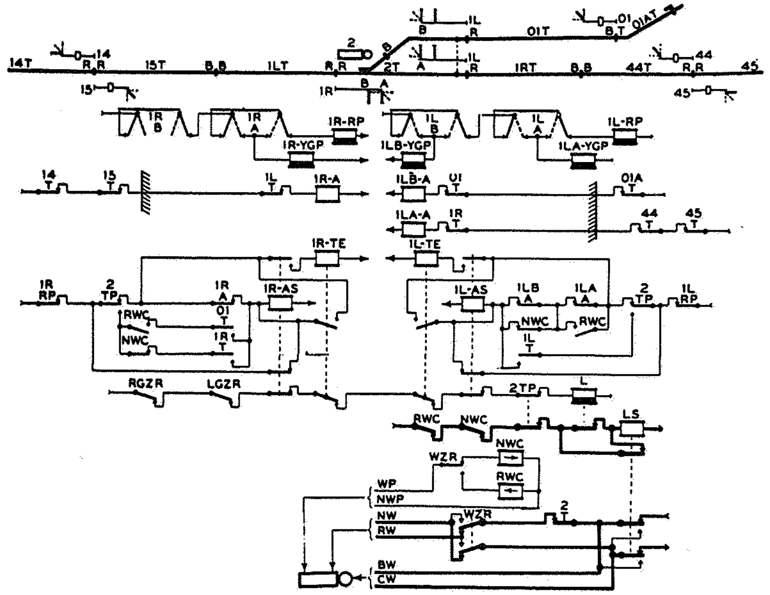

14T
15T
ILT
IRT
44T
45
2T
01T
1R-RP
1R-YGP
1LB-YGP
1L-RP
1LA-YGP
1R-A
1LB-A
1LA-A
01A
1R-TE
1L-TE
1R-AS
1L-AS
RWC
NWC
RGZR
LGZR
2TP
L
LS
WZR
WP
NWP
NW
RW
BW
CW

Figure 925. Relay interlocking locking and switch control circuits.

respondence with relay **WZR**, relay **RWC** will pick up to remove energy from relay **LS**. The dropping of relay **LS** disconnects battery from the switch machine and shunts its control wires to protect against false operation from crosses.

Back contacts of relays **RGZR** and **LGZR** are included in the control of relay **L** to deenergize this relay when an attempt is made to clear a signal. This is to permit including a back contact of the **L** relay in the signal-control circuits to check that the locking is in force before a signal can be cleared.

Home Signal Controls

Home signal controls check the proper alignment and locking of the switches in the route, the opposing home signal at stop and the condition of the block to the next signal in advance.

Referring to Figure 926, let us assume that signal **1RA** is to be cleared to the right over the switch normal. Placing the control lever in the right position picks up relay **RGZR**, which drops relay **L**, closing the circuit from **1RA** signal coil over a front contact of **2TP**, a front contact of **1LAS** to check that opposing signals are at stop, back contacts of relays **L** and **LS** to check that energy is removed from the switch machine, front contact of relay **NWC** checking that the switch points are over and locked normal in correspondence with the switch control, front contacts of the track relays of the section between the plant and signal 45, then to battery over front contacts of clear repeater of 45 signal **45YGP**. With **45YGP** up, the polarity on the circuit is such that **1RA** will display a green aspect. With

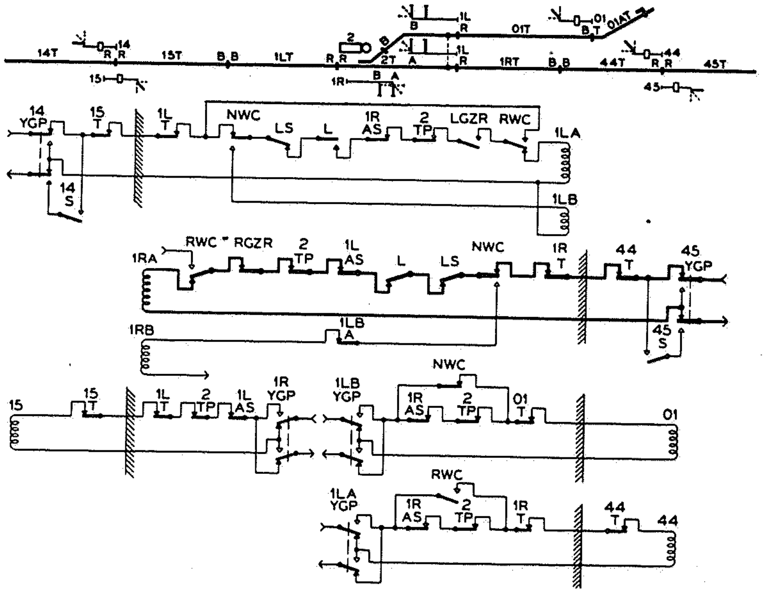

14T
15T
ILT
IRT
44T
45T
14 YGP
14 S
NWC
LS
L
1R AS
2 TP
LGZR
RWC
1LA
1LB
1RA
RWC
RGZR
1L AS
45 YGP
45 S
1RB
1LB A
1R YGP
1LB YGP
1LA YGP
01
44
15

Figure 926. Relay interlocking signal control circuits.

45YGP down, indicating that signal 45 is displaying a stop aspect, its directional stick relay 45S must be up to apply a polarity such that signal 1RA will display a yellow aspect.

It will be noted that had the switch been reverse, RWC up, and NWC down, a local circuit including the plant selections would have been closed to the coil of signal 1RB over a front contact of 1LBA to check the condition of the branch line to the extent that it is track circuited.

The control of the left signals is similar to that just described for the right signals except that both left signals receive polar energy from the signal in advance.

Approach Signal Controls

Approach signal controls, Figure 926, are taken over front contacts of all track relays between them and the opposing home signals. A front contact of the opposing AS is included to insure that opposing home signals are at stop. The circuits are then pole changed on the home signal YGP relays so as to cause the approach signals to display approach (yellow) aspects when the home signals are at stop and proceed (green) aspects when the home signals are clear.

When the opposing AS relay or the track relay within the plant is down for a route that does not conflict with an approach signal, it is shunted out of its circuit by front contacts of the NWC or RWC relays, as shown in the controls of signals 01 and 44.

The circuits discussed and shown here are typical for a small plant and become more complex as the plant increases in size with more functions to be controlled, but the fundamental principles involved remain the same.

ENTRANCE-EXIT INTERLOCKING

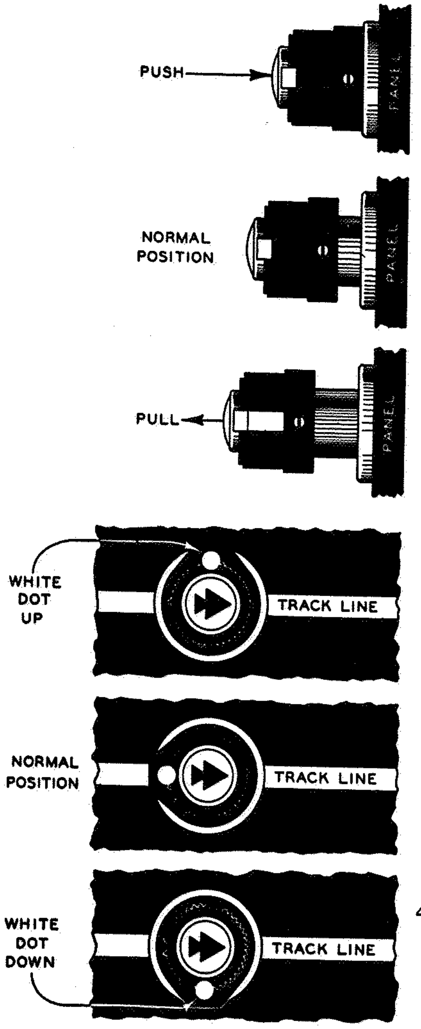
INTRODUCTION

The basic idea behind NX was that a route has an entrance and an exit. The term NX was coined by the General Railway Signal Company from the first syllables of the words *en*-trance-ex-it. On a miniature track diagram is placed an entrance knob at every possible entrance and an exit button at every exit. The entrance knobs are physically represented by interlocking signals on the ground.

ENTRANCE KNOBS

A stationary arrow in the middle of the entrance knob indicates the direction in which the signal governs. The entrance knob can be manipulated in four ways as shown in Figure 927. Each manipulation has a distinct purpose, thus:

1. PUSHED—When the route is lined up by pushing the entrance knob and the exit button, the passage of the first train over the route restores everything to normal. Hence, this manipulation provides automatic route restoration.
2. PULLED—When the route has been lined up by pushing the entrance knob and the exit button, and the operator decides to cancel the route, he may do so by pulling the entrance knob. If the train is not already on the approach track, he can immediately line up another route for it; otherwise he must allow a predetermined time to elapse before trying to line up another route.
3. TURNED UP—When the route is lined up by turning the entrance knob up, the route is held for a succession of trains. The signal is given for high- or medium-speed moves and repeatedly clears after each train leaves the block. Everything is restored to normal manually by turning the entrance knob back to normal, except that route locking of switches remains in effect as required by ordi-



1. PUSHED like a push-button, returning to its normal position by spring action.

(Side view is shown)

2. PULLED, returning to its normal position by spring action.

3. TURNED so that the white dot or marker is ABOVE the knob.

(Front view is shown)

4. TURNED so that the white dot or marker is BELOW the knob.

Figure 927. Entrance knob manipulations.

nary interlocking practice, and is so indicated on the panel.

4. TURNED DOWN—When the route is lined up by turning the entrance knob down, the route is again held for a succession of trains, and the signal is given for low-speed moves only. This signal may or may not be track-circuit controlled, depending on railroad practice. Everything is restored to normal manually by turning the entrance knob back to normal, except that route locking of switches remains in effect.

The entrance knob can be provided with all four manipulations, or only as many as are required for the purpose. The operator is able to line up routes with characteristics that suit the demands of traffic. If a succession of trains is to use the same route, he turns the entrance knob and holds the route. If each train requires a new route, he pushes the entrance knob and allows the train to restore everything to normal.

Entrance Knob Indications

The entrance knob may be provided with one lamp to display a single color, or with two lamps to display two different colors. There are three conditions that may be indicated by lights in the entrance knob (1) the route is initiated, (2) the route is complete and (3) the signal is clear.

With one lamp, usually white, in the entrance knob a flashing light indicates the route is initiated and a steady light indicates the signal is clear.

With two lamps in the entrance knob, two types of indications are available: (1) a steady red light indicates that the route is initiated and a steady green light indicates that the signal is clear, (2) a flashing red light indicates the route is initiated, a steady red light the route is complete but the signal has not yet cleared, a flashing green light the low-speed signal is clear, and steady green light indicates that the high- or medium-speed signal is clear.

EXIT BUTTONS

The exit button is a simple pushbutton of the spring-return type. An arrow on its face shows the direction in which the train leaves the route.

TEST KEYS

Switches can be thrown individually by means of test keys. Switches in transit are indicated by the switch correspondence lights.

PANEL INDICATIONS

Indications in the panel tell when a route is lined up, when a route is locked up, when the switch is in correspondence, when track circuits are occupied and available exit points.

On the movable route indicator panel in Figure 928:

1. The route lined up is shown by the movable route indicator, which snaps into position called for by the route when the operator presses the exit button. When no route is called for, it indicates switch position.
2. The route locked up is shown by the illumination of the lock light at the point of the route indicator.

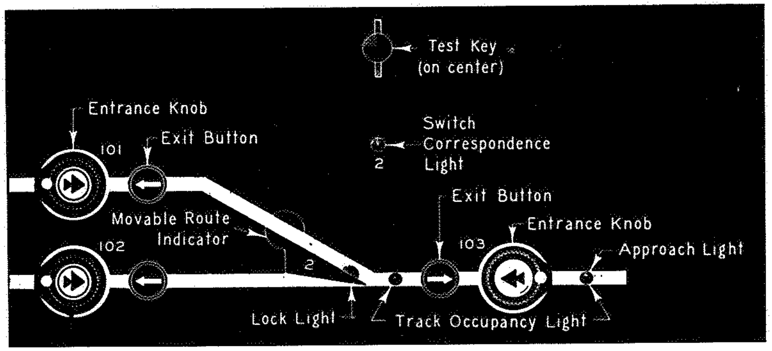
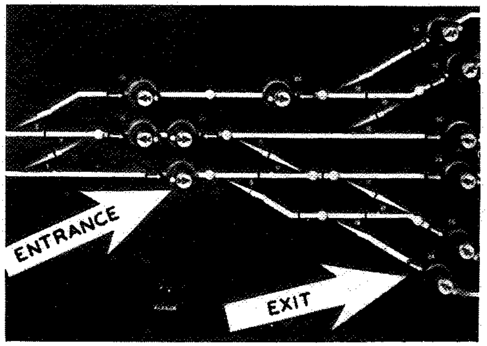

Test Key
(on center)
Entrance Knob
101
Exit Button
Switch
Correspondence
Light
2
Exit Button
Entrance Knob
103
Approach Light
Movable Route
Indicator
102
2
Lock Light
Track Occupancy Light

Figure 928. Movable route indicator panel.

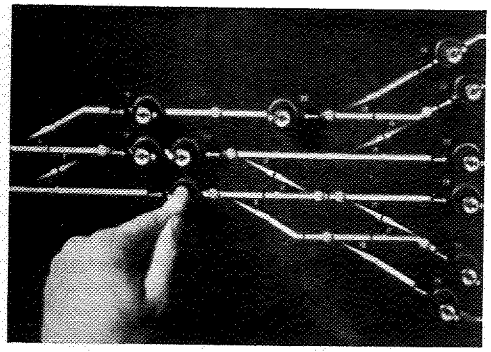
3. The illumination of the switch correspondence light shows that the switch is out of correspondence with the position called for by the route. It may be in transit or stalled. The same light is illuminated if a maintainer hand-cranks the switch machine in the field, and it remains illuminated until the switch machine is cranked back into correspondence.
4. Track occupancy is indicated by the illumination of the track occupancy lights.
5. The indication of available exit points can be provided by the use of an exit button which contains a light. The light is illuminated (after initiation has taken place) in every exit button to which a route may be lined up.

ROUTE SELECTION

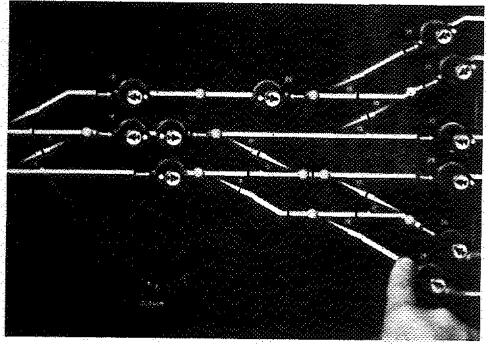
The following picture sequence shows how a route is lined up on a movable route indicator panel:


ENTRANCE
EXIT

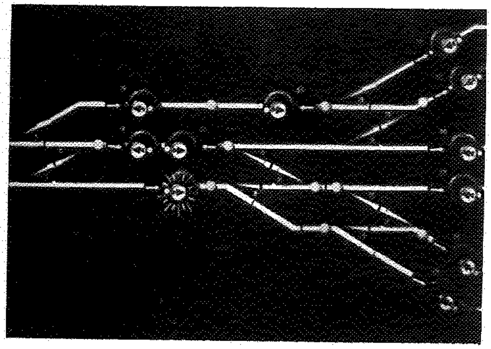
The sequence shows how the operator lines up a simple route between two opposing signals.



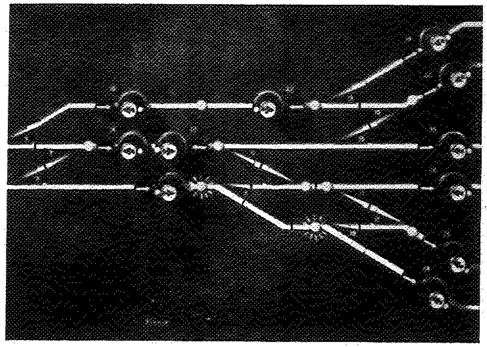
The operator presses the entrance knob corresponding with the point where the train will enter the route. The light behind the arrow begins to flash, indicating that a route has been initiated at that point.



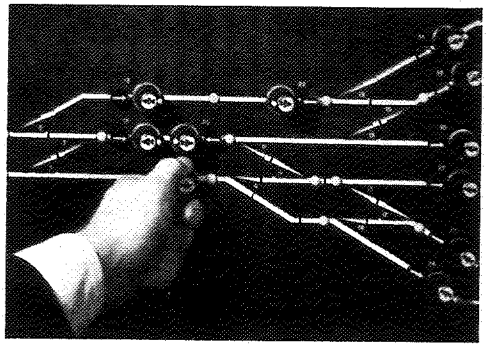
He next presses the exit button corresponding with the point where the train will leave the route. With entrance and exit points thus established, the system automatically throws the switches and clears the signals.



Route indicators position to outline the route; red "lock lights," behind the pointed ends of the route indicators, show the switches are locked; a steady white light in the entrance knob shows the signal is clear.



As train travels over route, white track lights are illuminated. Light in entrance knob is extinguished as signal goes to stop behind the train. Red lock lights are extinguished as switches in route are released.

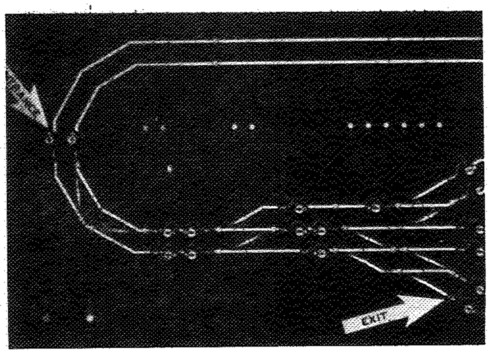


If the operator wishes to change the route before the train accepts it, he first cancels by pulling the entrance knob. He lines up the new route as described before.

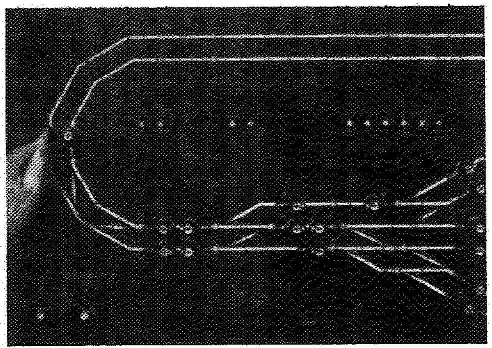
End-to-End Routes

The "end-to-end" route line-up saves time where many intermediate signals are involved.

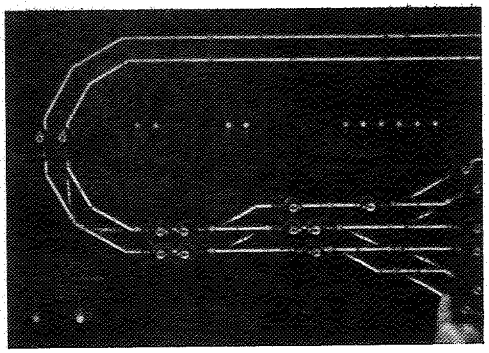
The following picture sequence shows how an end-to-end route is lined up on a movable route indicator panel:



A long route comprising several sections could be lined up similarly from beginning to end by pressing each entrance knob and exit button having an arrow pointing in the same direction.

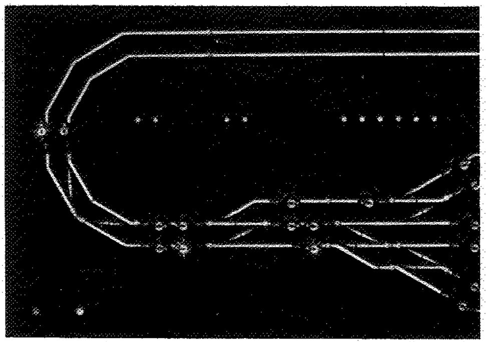


The end-to-end feature reduces this manipulation. The operator presses the entrance knob at the very beginning of the route.

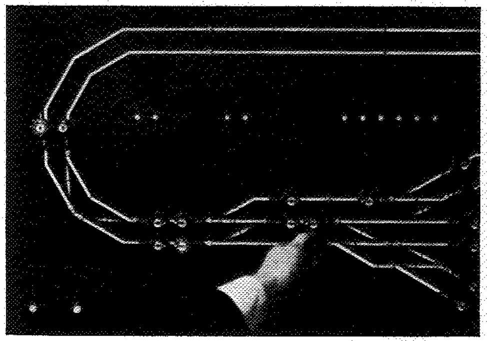


He skips over the intervening buttons and presses the exit button at the very end of the route.

Route indicators line up, switches operate, signals clear (including the intermediate ones), and steady lights appear in the corresponding entrance knobs.



If the operator wishes to cancel any section of the route, he pulls the entrance knob. This puts the corresponding signal to stop and, if no train is approaching, releases the switches in that section.

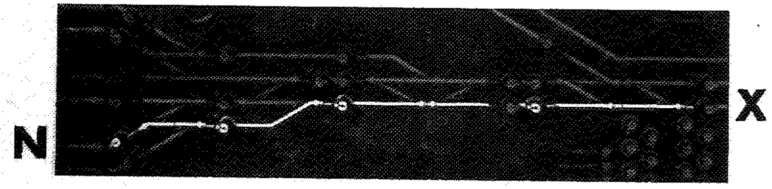


And so it goes, the NX system in each case automatically operating the required switch and signal functions.

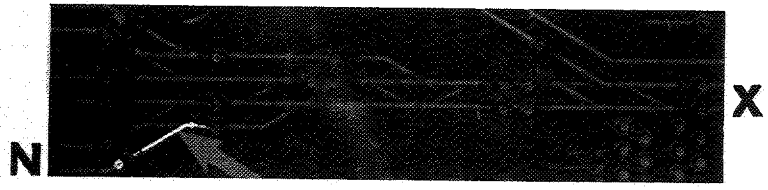
Automatic Route Selection

In a terminal or yard there usually are several routes between any two points. If one is obstructed, the operator can line up a second; but this takes time, as the optional or secondary routes are usually more complicated than the straightforward, preferred route.

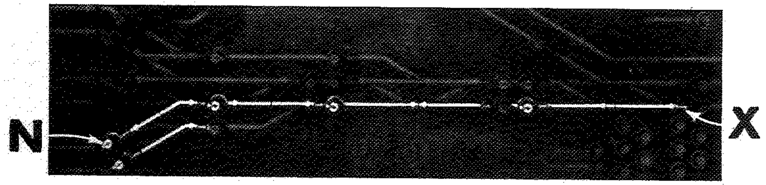
With NX, however, the operator presses the entrance knob, and the exit button at the two ends of the route. If the preferred route is not available, the next best optional route is lined up instantly. The picture sequence of a movable route indicator panel tells the story.



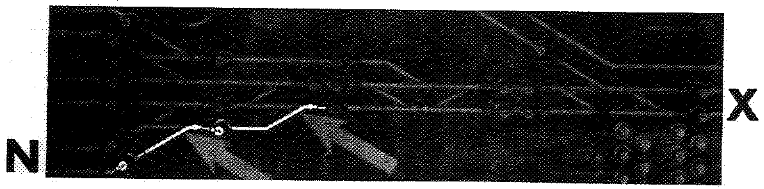
Here is preferred route from entrance "N" to exit "X."



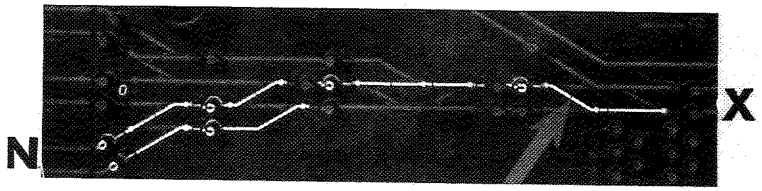
Suppose that, before operator lines up route from N to X, the switch (arrow) is used by the short route indicated.



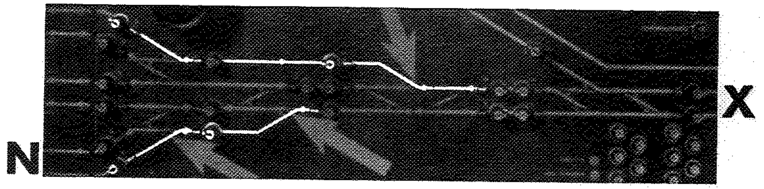
Now if the operator presses entrance knob N and exit button X, the NX system automatically lines up this next best route.



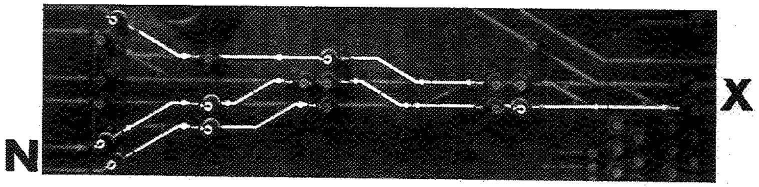
To go a step further, suppose that the two switches (pointed out by the arrows) are used by the short route indicated, and the operator still wishes to line up the route from N to X.



This is the new route N to X. Note there are two possible crossovers that could have lined up, but the NX system chooses the one marked with an arrow because it is a high-speed crossover.



A third possibility exists in that the two routes indicated may be lined up. To line up a route now from N to X would ordinarily take some "figuring" on the part of the operator.



With NX, he again presses entrance knob N and exit button X; a route is immediately lined up.

NX CIRCUITS FOR A NEAR GROUP

INITIATION AND COMPLETION CIRCUITS

For the purpose of illustration, a simple interlocking is considered in Figure 929, having a turnout powered by a Model 5C switch machine, two single-arm back-up dwarf signals 101 and 102, a three-arm high signal, the "A" arm for high-speed moves over the switch normal, the "B" arm for medium-speed moves over the switch reverse, and the "C" arm for low-speed "call-on" moves. Signals 101, 102 and 103C are not track circuit controlled.

On the control panel the layout is controlled by three entrance knobs and three exit buttons. Entrance knobs 101 and 102 can be turned down only, to initiate a route for a low-speed back-up move. Entrance knob 103 can be pushed, pulled, turned up or down. When pushed or turned up it initiates a high- or medium-speed route; when turned down, a low-speed route.

The following sequence of events occur in the initiation and completion circuits when a medium-speed route is lined up from 103 to 101 by pushing entrance knob 103 and exit button 101:

1. The operator pushes entrance knob 103 and picks up 103GLPR relay; the path of the current flow is shown by the heavy line. When he removes his finger from the knob, current continues to flow through a normal (N) contact of the knob, also a sliding contact which is broken only if the knob is pulled or rotated, through 103GLPR front contact 1, TPR front contact 1 to the winding of 103GLPR. This constitutes a stick circuit which is broken either by a train shunt on track 2T or by pulling (or turning) the entrance knob, should the operator wish to cancel the route manually.
2. The operator pushes exit button 101.
3. Exit relay 101XR picks up and sticks up through its own front contact 2 as long as 103GLPR remains up.
4. Reverse relay 2RR picks up through front contact 3 of 101XR.

Before going any further, however, it is necessary to fix a few principles in mind, as illustrated in Figure 929.

1. When the knob is pushed, the GLPR relay is picked up through a contact on the track repeater, this circuit producing the automatic route restoration feature. When the train shunts the track, the initiation and completion circuits are deenergized and everything restored to the way it was before the route was lined up. The switch, however, stays in the last-operated position.
2. When the knob is turned up (L), the GLPR relay is held energized until the knob is turned back to normal.
3. When the knob is turned down, the initiation network is energized without energizing the GLPR relay.
4. Each exit button has a repeater relay (XR), which sticks up while the route is held.
5. The exit relay picks up the normal (NR) or reverse (RR) relays in the completion circuit, which in turn position the NWZR or RWZR relays to call for the switch normal or reverse.
6. There are two initiation networks and two completion networks—one for each direction. The function of the initiation network is one of exploration, sending out branches to determine the available exit points. It also marks the points of route convergence (by the YR relays) so that the completion network can follow back to the original entrance point. The completion network calls for the switch position as it follows back to the entrance, and cuts off the unused branches of the initiation network.

7. The time involved in the cascade at each switch, as the completion circuit passes from exit to entrance, is that required for a single relay to pick up. It is so short that the speed of the route line-up is not materially affected. It has the beneficial effect of distributing the initial starting current surge of the switch machine motors, thus preventing an unnecessarily high peak load of short duration.

When a route is to be lined up over a switch for a trailing move, say from 101 to 103, a route selecting relay (YR) comes into action. There is a YR relay for every trailing switch, and, in Figure 929, it is picked up when a trailing move calls for the switch normal.

To illustrate the function of the 2YR relay, the following sequence of events occur to line up a route from 102 to 103:

1. The operator turns entrance knob 102 down (L) to energize the initiation network.
2. Provided no conflicting route has been lined up, this picks up 2YR.
3. The circuit continues through 2YR front contact 2 to the left side of the winding of 103XR.
4. The operator pushes exit button 103, and 103XR picks up, sticking up through its own front contact as long as knob 102 is turned down.
5. The completion circuit, through 103XR front contact 3 and 2YR front contact 4, picks up 2NR, which in turn picks up 2NWZR.

If a route is lined up from 101 to 103, 2YR remains down. When 103XR picks up, it picks up 2RR through 2YR back contact 3, which in turn picks up 2RWZR.

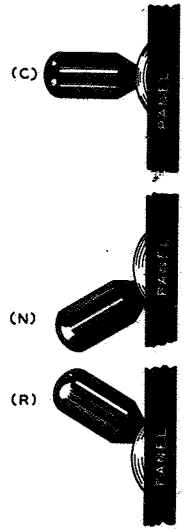
From the foregoing it can be seen that the YR relay is always used where routes converge for a trailing move. It may be put into either leg of the "Y," thus producing a definite bias in favor of the leg in which its winding is connected. If entrance knobs 101 and 102 are turned before exit button 103 is pushed, the route 102 to 103 will always line up because 2YR favors that route, being picked up by 102 entrance knob. This circuit feature of the YR relay has value in the selection of preferred and optional routes between two points in an interlocking.

The principles with a crossover are exactly the same as those with a single switch. Since there are two track convergences with a crossover, there are two YR relays. There are two NR relays (one for each of the parallel tracks) and one RR relay. Hence there are three route selecting relays for each single switch and five for each crossover. Only one NWZR and RWZR relay is required.

TEST KEY OPERATION AND ROUTE LOCK CIRCUITS

Test keys are located in any convenient space on the control panel. They are provided for test purposes, enabling their respective switches and crossovers to be thrown individually. They are not generally used in regular operation.

The handle of the test key moves in a vertical plane in three positions. The center (C) position (jutting out from the panel at 90 degrees) is the inoperative position; the downward position (N) calls for its respective switch normal; and the upward position (R) calls for the switch reverse. Test keys are normally left in the center position.



A switch cannot be thrown by its test key if it is locked or already positioned by a route call. Likewise, if a switch is held in one position by its test key, a route can be given only over that position of the switch.

In the circuits, Figure 929, it can be seen that the NR and RR relays have three independent windings. One is used in each of the two completion networks while the third serves two circuits:

1. It is connected to the test key.
2. It is connected to a stick circuit which is energized through a back contact of the lock stick relay.

The NR and RR relays are so interlocked that they cannot both be picked up at the same time. Should the NR relay be picked up by the completion network, the RR relay cannot be picked up by the test key when it is placed in the reverse position. The RR relay will not pick up even after the control by the completion network is broken. The test key must be restored to the center position and operated again, thus preventing preconditioning of the switch and providing the equivalent of an electric lever lock. The reason for this is that the energy through the reverse (R) contact of the test key is passing through a front contact of relay NR to the winding of NR, thus holding it energized as long as the test key is in this operated position.

After the NR or RR relays have been picked up by either the completion network or the test key, they remain up as long as the switch is electrically locked (LSR relay down) even though the route call is cancelled and the test key is in its center position. While the NR or RR relays remain stuck up, a route cannot be lined up over the switch in any but the locked position.

The NWZR and RWZR relays are picked up directly by their respective NR or RR relays. In the case of parallel routes, either NR relay up will pick up the NWZR relay. These relays will be held in their last called for position by a stick circuit through a back contact on the opposite relay. They are used for controlling the switch machine and the movable route indicator.

SWITCH CONTROL AND INDICATION CIRCUITS

The switch control and indication circuits shown in Figure 930 are that part of the complete circuits which may be found in the tower. The circuits through the switch machine itself are standard and shown previously in Figure 905.

Referring to the switch control circuit, assume that the operator is lining up a route over switch 2 reverse, and, at the time he presses the exit button, the switch is in the normal position. The sequence of relay operation is as follows:

1. Relay 2RR, Figure 929, picks up and energizes the reverse switch control relay 2RWZR.
2. The controller in the switch machine is operated to its reverse position through contacts on 2RWZR relay, Figure 930, with relay 2LSR picked up.
3. When 2RWZR is picked up, 2NWZR, Figure 929, and 2NWCR, Figure 930, drop. Relay 2RWCR, Figure 930, will remain down until the switch machine is fully reversed and locked. Reversal in mid-stroke is permitted at any time when the LSR relay is energized.
4. When the switch machine locks up, the energy to the switch repeater circuit will be pole-changed and the 2RWCR biased relay will pick up.

The RWCR relay is used in the signal circuits to select the proper signal over the switch. One or the other of the correspondence relays NWCR and RWCR is normally energized, picking up when the switch is in correspondence with the last call (NWZR or RWZR up).

Note that the circuit organization is such that a signal cannot be cleared over a switch unless energy to the switch machine has been cut off. In order to clear the signal, the LSR relay must be down. This automatically removes energy from the operating circuit of the switch machine.

The stick circuit provided on the NWZR and RWZR relays, Figure 929, maintains these relays in the energized position and assures follow through if 2NR or 2RR is released by the operator's cancelling the route while the switch is in motion (if the lock stick relay is up). It also causes the switch machine to lock up if it is left unlocked by hand-cranking.

Switch correspondence is indicated by the switch correspondence light, Figure 930, which lights up whenever both the NWCR and RWCR relays are down. Both these relays will be deenergized as soon as the NWZR or RWZR relay picks up at the start of a switch movement. They will remain down until such time as the switch machine comes into correspondence as determined by the call initiated by the NWZR or RWZR relay. Any out of correspondence condition initiated in the field, such as hand-cranking of the switch machine, will also cause both these relays to be deenergized, thus lighting, the correspondence light. The light will remain illuminated until the switch machine is restored and locked up in the position called for in the tower.

The lock light associated with the switch is lighted when the NR or RR relay is picked up or when the LSR relay is released.

The movable point indicator responds to the position of the NWZR and RWZR relays. It thus repeats the last route called for by the control circuits.

CODED CONTROL SYSTEMS

The unit wire type of control has already been described under Basic Circuits, page 908.

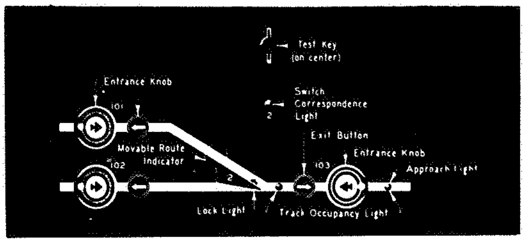
The fundamental purpose or object of the code system is to do the same work over two line wires that is done over several line wires in a unit-wire system. In a code system, the circuits between the control office and field are not organized on the "normally closed" circuit principle. This principle applies only to the circuits relied upon for safety, such as the switch and signal control circuits, approach locking, etc., previously covered. These circuits are the same for a code-type system as for the unit-wire type. The code part of the system, however, is entirely open circuit, as failures of the code apparatus do not affect safety. The code communication circuits are used to transmit controls and indications with the minimum of apparatus and line wires and as reliably as can be done with an open-circuit scheme.

For a more detailed description of the principles of coding, see the section on centralized traffic control.

THE SYNCROSTEP SYSTEM

Syncrostep is a coded remote control system for controlling large or small interlockings over two line wires between the control office and the remote interlocking. The term "Syncrostep" is derived from the synchronous stepping produced by two mechanical oscillators, one at each end of a line circuit. These oscillators are normally locked, with their spiral springs wound up. When the operator turns a lever, or when an indication is to be transmitted from the remote location, the oscillators are unlocked at the same time and swing or oscillate together. In this way the control office and the field location step in synchronism—hence the term "Syncrostep."

In other coded systems the stepping is regulated by the control office, the field location receiving its cue from the office


Test Key
(on center)
Entrance Knob
101
Switch
Correspondence
Light
2
Exit Button
Movable Route
Indicator
102
Entrance Knob
103
Approach Light
2
Lock Light
Track Occupancy Light

SEQUENCE OF EVENTS WHEN LINING UP
A ROUTE FROM 103 to 101

1. Operator presses 103 entrance knob.
2. 103GLPR picks up and sticks up.
3. Operator presses 101 exit button.
4. 101XR picks up and sticks up.
5. 2RR picks up which in turn picks up 2RWZR calling for switch 2 reverse.

Figure 929

INITIATION AND COMPLETION CIRCUITS; ALSO TEST KEY OPERATION AND ROUTE LOCK

SYMBOLS

Entrance Knob

-(N)-	Contact broken only when knob is pulled or rotated Contact made only when knob is pushed
-(L)-	Contact made only when knob is rotated left (counterclockwise)
-(R)-	Contact made only when knob is rotated right (clockwise)

Exit Button

	Two-position exit button (spring-return)

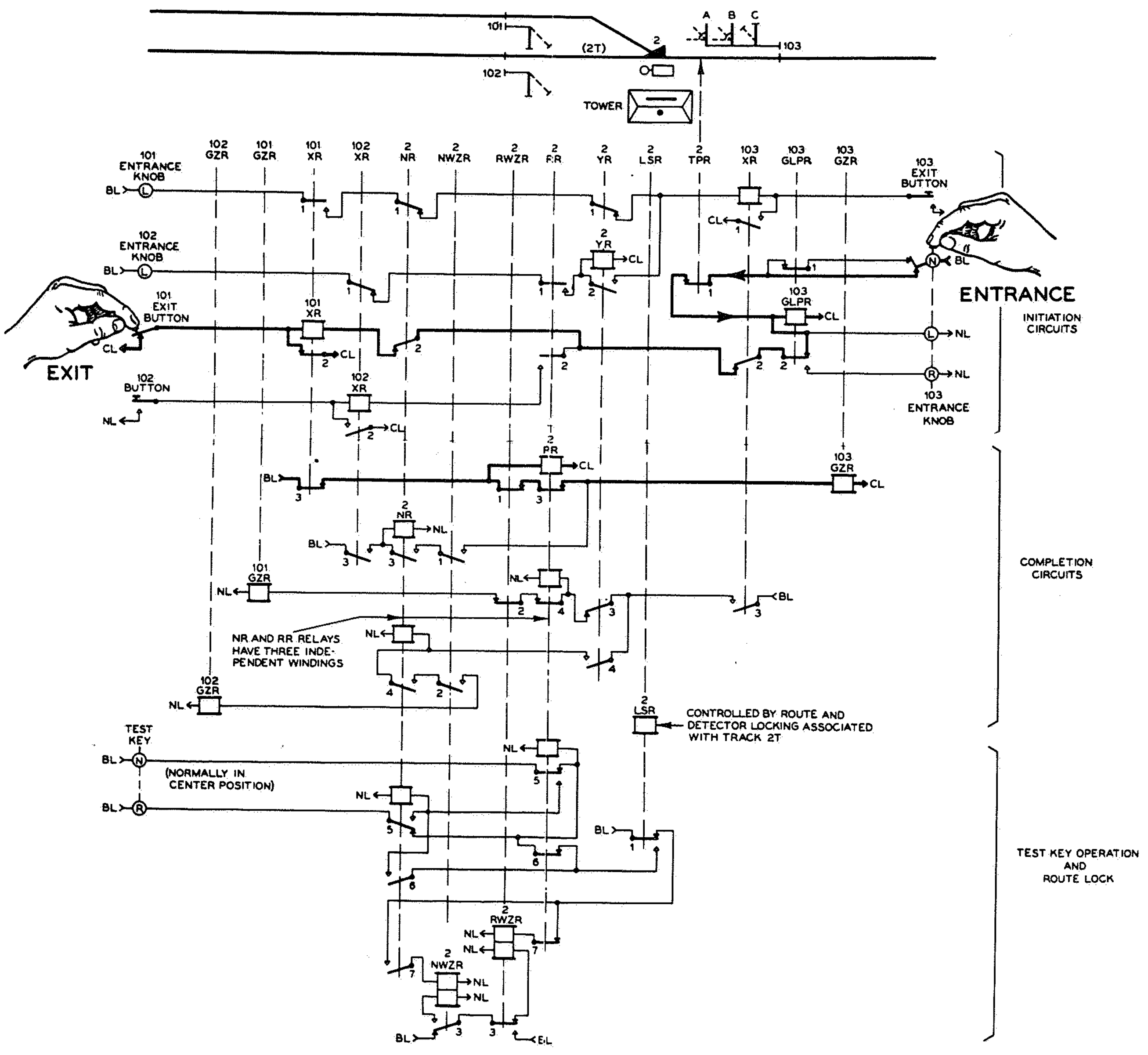
Test Key

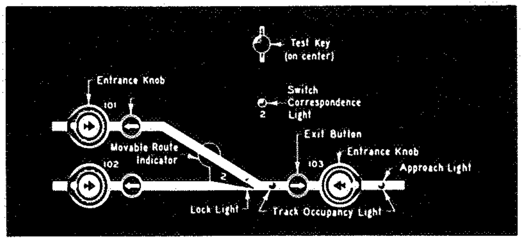
-(N)-	Contact made only when key is operated downward
-(R)-	Contact made only when key is operated upward
NL←	Negative split battery low-voltage supply
BL>	Positive split battery low-voltage supply
CL←	Common split battery low-voltage supply

NOMENCLATURE

GLPR	Signal lever relay	Repeats operation of entrance knob
GZR	Signal clearing relay	Clears signal after route completed
LSR	Lock stick relay	Locks the route
NR	Normal relay	Calls for route over switch normal
NWZR	Switch control relay	Positions switch normal
RR	Reverse relay	Calls for route over switch reverse
RWZR	Switch control relay	Positions switch reverse
TPR	Track repeater relay	Repeats track relay
XR	Exit relay	Completes route, starts completion network functioning
YR	Route selecting relay	Selects route to be followed by completion network

NOTE: These circuits are simplified for the purpose of illustration.


101
102
(2T)
2
A B C
103
TOWER
101 ENTRANCE KNOB
102 GZR
101 GZR
101 XR
102 XR
2 NR
2 NWZR
2 RWZR
2 FR
2 YR
2 LSR
2 TPR
103 XR
103 GLPR
103 GZR
103 EXIT BUTTON
102 ENTRANCE KNOB
101 EXIT BUTTON
EXIT
ENTRANCE
INITIATION CIRCUITS
102 BUTTON
103 ENTRANCE KNOB
2 PR
COMPLETION CIRCUITS
NR AND RR RELAYS HAVE THREE INDEPENDENT WINDINGS
CONTROLLED BY ROUTE AND DETECTOR LOCKING ASSOCIATED WITH TRACK 2T
TEST KEY
(NORMALLY IN CENTER POSITION)
TEST KEY OPERATION AND ROUTE LOCK
BL
CL
NL
EL


Test Key
(on center)
Entrance Knob
101
Switch
Correspondence
Light
2
Exit Button
Movable Route
Indicator
102
2
103
Entrance Knob
Approach Light
Lock Light
Track Occupancy Light

SEQUENCE OF EVENTS WHEN LINING UP
A ROUTE FROM 103 to 101

1. 2RR picks up (Figure 929) energizing 2RWZR. Lock light lights, and the route indicator reverses.
2. 2NWZR and 2NWCR drop. The switch correspondence light lights.
3. The switch machine unlocks, operates reverse, and locks up.
4. 2RWCR picks up, extinguishing the switch correspondence light.

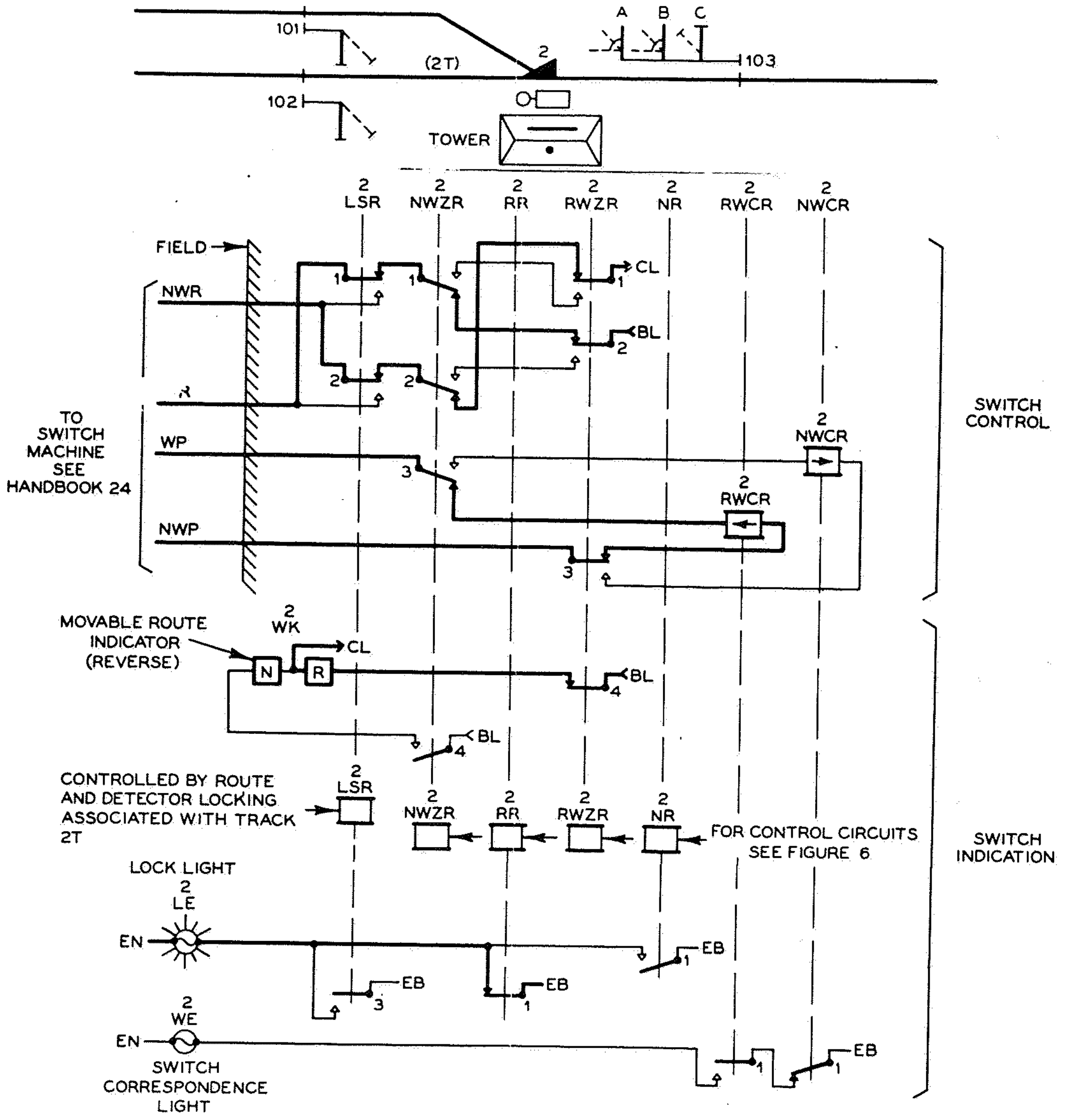
Figure 930

SWITCH CONTROL AND INDICATION CIRCUITS

NOMENCLATURE

LSR	Lock stick relay	Locks the route
NR	Normal relay	Calls for route over switch normal
NWCR	Switch correspondence relay	Checks normal switch correspondence
NWZR	Switch control relay	Positions switch normal
RR	Reverse relay	Calls for route over switch reverse
RWCR	Switch correspondence relay	Checks reverse switch correspondence
RWZR	Switch control relay	Positions switch reverse
EN EB	Light energy	

NOTE: These circuits are simplified for the purpose of illustration.


101
102
(2T)
2
A
B
C
103
TOWER
2 LSR
2 NWZR
2 RR
2 RWZR
2 NR
2 RWCR
2 NWCR
FIELD
NWR
R
WP
NWP
TO SWITCH MACHINE SEE HANDBOOK 24
CL
BL
2 NWCR
2 RWCR
SWITCH CONTROL
MOVABLE ROUTE INDICATOR (REVERSE)
2 WK
N
R
CL
BL
BL
CONTROLLED BY ROUTE AND DETECTOR LOCKING ASSOCIATED WITH TRACK 2T
2 LSR
2 NWZR
2 RR
2 RWZR
2 NR
FOR CONTROL CIRCUITS SEE FIGURE 6
SWITCH INDICATION
LOCK LIGHT
2 LE
EN
EB
EB
EB
2 WE
EN
SWITCH CORRESPONDENCE LIGHT
EB

before making each step. With Syncrostep, the control office and the field location step independently once they get the cue to start. The two oscillators are so precisely manufactured that they remain in step for the duration of the complete transmission cycle.

THE OSCILLATOR

The oscillator used in Syncrostep is similar to the code transmitter used in coded track circuit work. The difference, however, is that the Syncrostep oscillator, Figure 931, is normally locked or latched magnetically with the spiral spring wound up. The power to hold it locked comes by energizing the coil and creating a strong electromagnetic pull on the armature.

When energy is cut off the coil, the armature is released. Because of the torsional force of the spring, the armature oscillates freely—like the balance wheel of a watch. Stepping relays count the swings of the armature and cause energy to be applied to the coil at the end of the transmission cycle to again lock the armature.

Since only a few complete oscillations are required for a transmission cycle, there is no appreciable decay in the amplitude of the oscillations, although each successive oscillation is a little shorter because of overcoming contact pressure, friction and air resistance. The reduction in travel has no effect upon the rate of stepping or the duration of contact closure. Thus a highly accurate rate of stepping is provided.

According to Webster, an "oscillation" is "a single swing from one extreme limit to the other of an oscillating body." The period of oscillation is defined as the time occupied by a single oscillation, counting from the instant when the armature is at one extreme position to the instant when it next arrives at its other extreme position.

Syncrostep oscillators produce 540 oscillations per minute, hence their period of oscillation is 1/540 minute or 1/9 second.

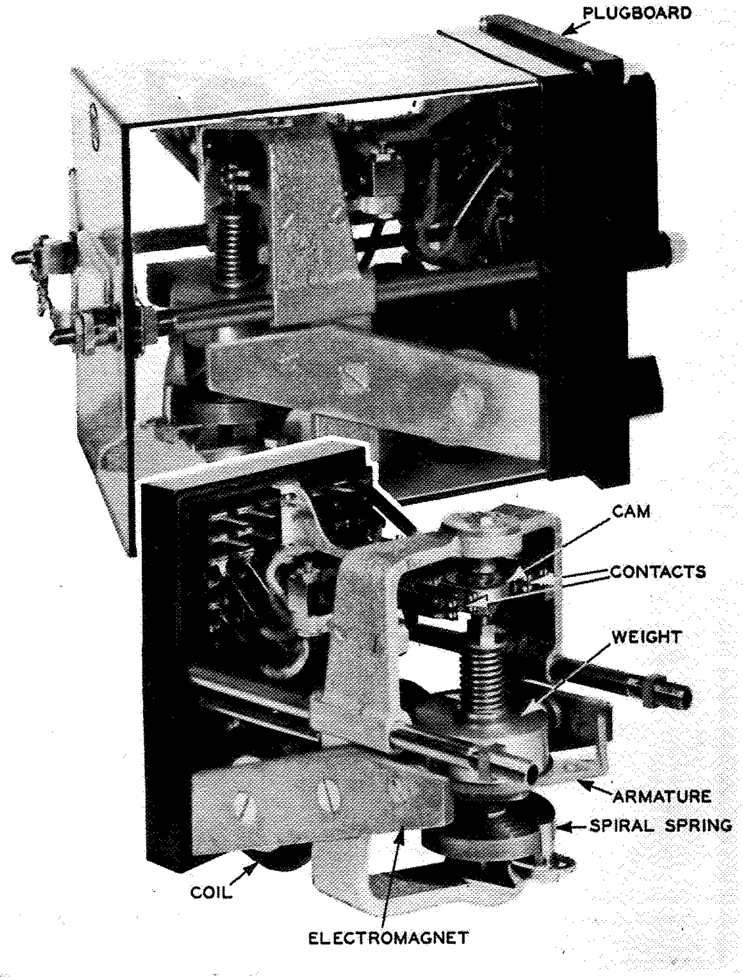


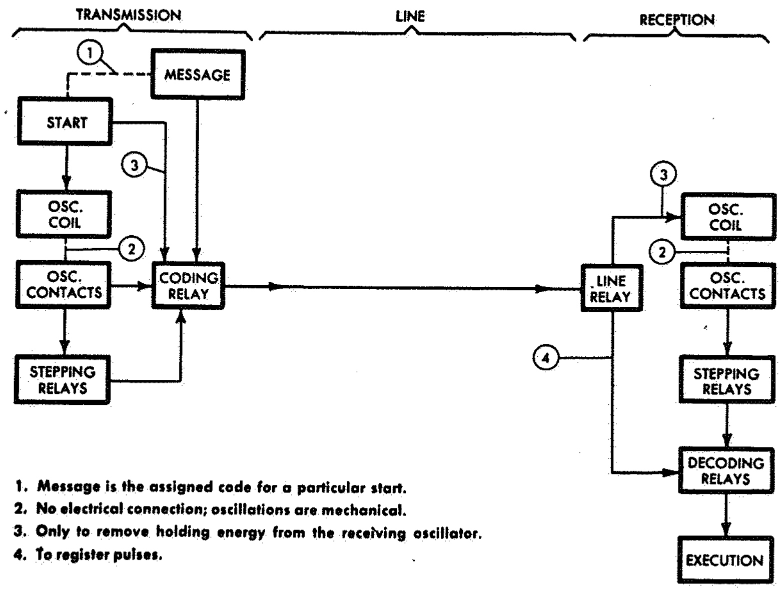
Figure 931. Mechanical oscillator.

The rate may vary slightly between oscillators because of variations in manufacture, the variation being not greater than ±2 oscillations per minute. That is, one oscillator may operate at 538 oscillations per minute and another at 542 oscillations. For the few oscillations used during the transmission of a control or an indication, this variation is so small as to be negligible.

OPERATION

To control a device in the field, Figure 932, the operator positions the lever on his control panel. This act energizes a lever repeater relay which sets up a particular control code through its front contacts.

The lever repeater starts the control cycle by releasing the oscillators. As the system steps through the cycle the line circuit is either energized or deenergized on each step, depending on the code connections through the lever repeater relay. The terms commonly used are "Marks" and "Spaces" for the energized and deenergized conditions of the line circuit.



1. Message is the assigned code for a particular start.
2. No electrical connection; oscillations are mechanical.
3. Only to remove holding energy from the receiving oscillator.
4. To register pulses.

Figure 932. Block diagram showing basic operation.

At the field location the presence of energy on the line circuit—or a Mark—is detected by the energization of a mark storage relay on that particular step. There is one Mark storage relay for each step. At the end of the control cycle of seven steps a check is made to see if an odd number of Mark storage relays are picked up. Then, and only then, is the switch or signal control relay energized on the eighth and final step, known as the "execution" or "clearout."

Assume that the device has operated in the field. The first inkling the Syncrostep has of this fact is the deenergization of a so-called "change" relay, whose stick circuit is taken through contacts of all the device repeater relays in series. Hence, whenever any change occurs in the field, the change relay goes down.

Like the lever repeater in the office, the field change relay starts an indication cycle. The code connections, which determine whether Marks or Spaces will be transmitted, are made on the switch, signal, and track repeater relays. Thus, if a signal is clear a Mark is transmitted, that is the line is closed; if the signal is at stop, the line is open.

As the system steps through the indication cycle, each device repeater relay has an opportunity to impress a Mark or a Space on the line.

At the control office these Marks and Spaces are detected by Mark detector relays, which, in turn, pick up or drop indication relays. Thus, if a track relay was down at the field location, a Mark would come in on the appropriate step, the Mark detector relay would pick up on that step and the corresponding track indication relay would drop to light the track light on the panel.

SIMPLEX OPERATION

What has just been described is known as "simplex" operation, that is, only one control cycle or one indication cycle can be in progress at one time. Simplex operation can be compared with a gauntlet track over which traffic can move only in one direction at a time.

Control transmission has priority over indication transmission. If several controls are waiting to go out, the indications will be stored until the line is free for transmission of the indications.

DUPLEX OPERATION

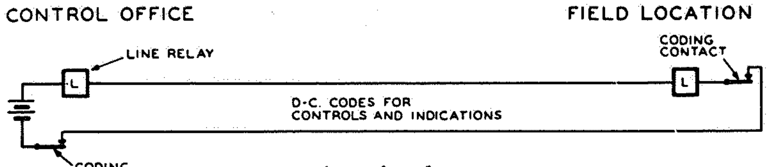
On some very busy layouts control transmissions could block and delay indication transmissions. This might be an operating handicap as the operator would not have immediate knowledge of events in the field.

To take care of this situation "duplex" operation is available, whereby controls and indications can be transmitted simultaneously and independently. In effect, it comprises two simplex systems, side by side, one using a control wire and common, the other using an indication wire and common, or a total of three line wires. The line circuit, if very long, can be reduced to two line wires by using carrier.

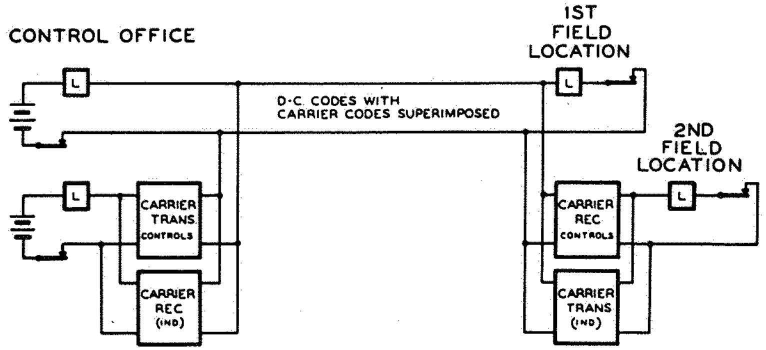
The choice between simplex and duplex is determined by the volume of traffic to be handled.

TYPICAL LINE CIRCUITS

A simplified sketch of a 2-wire simplex Syncrostep system is shown in Figure 933a. For controls, the coding contact at the control office opens and closes the line circuit in accordance with the code. For indications, the field coding contact interrupts the line circuit to transmit. In each instance, the coding contact at the receiving end is held closed to complete the circuit. Both line relays follow the code, of course, since this is a series circuit.


CONTROL OFFICE
FIELD LOCATION
LINE RELAY
CODING CONTACT
L
L
D-C. CODES FOR CONTROLS AND INDICATIONS
CODING CONTACT

a. 2-wire simplex.


CONTROL OFFICE
1ST FIELD LOCATION
2ND FIELD LOCATION
L
D-C. CODES WITH CARRIER CODES SUPERIMPOSED
CARRIER TRANS. CONTROLS
CARRIER REC (IND)
CARRIER REC CONTROLS
CARRIER TRANS (IND)

b. 2-wire simplex with carrier for an additional location.

Figure 933. Line circuit arrangement for simplex operation.

An additional interlocking may be controlled over the same two line wires. A second control machine would be installed at the office, or, if the machine is the sectional type, additional control sections would be installed. By using carrier, Figure 933b, the second field location is controlled by a second simplex system superimposed on the same two line wires. A carrier transmitter and receiver of one frequency handle the control codes, and a transmitter and receiver tuned to a different frequency handle the indication codes.

CARRIER UNITS

Carrier may be applied with Syncrostep—not so much to increase distance but to make it possible to use the same pair of wires.

The carrier units generally used are the transmitter and the receiver, Figure 934. The transmitter unit generates frequencies above the voice-frequency range, from about 12,000 c.p.s. to 30,000 c.p.s. The carrier frequency is interrupted in accordance with the code to be transmitted.

The receiver unit is connected to one winding of a double coil line relay. The second winding is biased by local energy.

With a carrier signal on the line—the equivalent of a Mark—the receiver output current is less than the bias current, and the relay armature assumes the bias position.

With no carrier signal on the line—the equivalent of a Space—the receiver output current is greater than the bias current, and the relay armature is pulled to the opposite position.

The transmitter consists essentially of an oscillator, a buffer stage of amplification, and a power amplifier. It is a keyed continuous-wave transmitter of a fixed frequency. The carrier signal is transmitted only when the keying circuit is closed—or in other words, when a Mark is placed on the line.

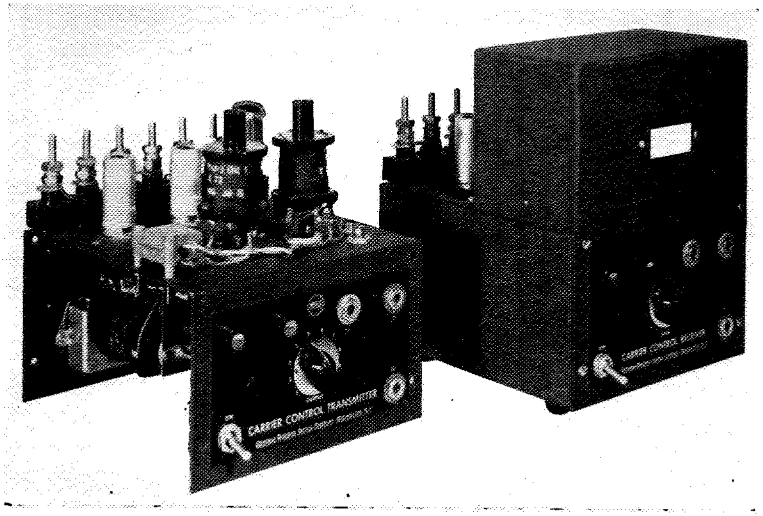


Figure 934. Receiver and transmitter carrier units.

The receiver is similar in physical construction to the transmitter. It has a voltage amplifier stage, a rectifier stage, and a relay tube. It is a narrow band receiver designed to accept one particular frequency and be unresponsive to all other frequencies.

7-STEP SIMPLEX SYSTEM

A control requires a cycle of either seven or eleven steps, depending on the size of the system. Either a Mark or a Space is transmitted on each step. As shown in Figure 935, an entire code of seven, or eleven, steps is assigned to perform one control, such as throwing a switch normal or throwing that switch reverse.

STEPS	1	2	3	4	5	6	8
CODE	M	M	M	S	S	S	M
FUNCTION	LOCKOUT	CONTROL					CHECK

Figure 935. Typical 7-step simplex control code.

In a simplex control code the character in the first step signifies whether the cycle is for the transmission of a control or an indication—a Mark is always used to identify a control code. The first step is used to lock out an indication cycle that might interfere with the transmission of a control cycle.

The next five steps comprise the actual control code. A maximum of 32 different control codes is available in the 7-step simplex system.

The seventh step is used to check the integrity of the code, and provides what is known as a "parity" check. Either a Mark or a Space is transmitted in this step to make the total number of Marks in the last six steps come out odd. This odd number of Marks makes up a fixed pattern at the control office, and the field location always expects to receive the corresponding pattern. Therefore, if a Mark is lost in transmission or an additional Mark is received due to picking up energy on the line circuit from an extraneous source, the faulty code reception is detected by the field examination, and the execution of the control is prevented. Thus a double error would be necessary to cause execution of an improper code.

INDICATION CODES

Because there are usually twice as many indications as there are controls required on any remote control installation, a double cycle is used for transmitting indications, the usual 7-step cycle being repeated to obtain 14 steps, Figure 936.

Steps Used For Identifying Stations	Max. No. of Stations Which Can Be Identified	Steps Left For Indications	Max. No. of Indications (Stations x Indications)
1	2	12	24
2	4	11	44
3	8	10	80
4	16	9	144
5	32	8	256

and so on.

Figure 936. Simplex system with 14-step indication cycle.

A field location is usually sub-divided into several groups, called stations, because of the complexity of the interlocking and the possible large number of indications. During the transmission of an indication code the station is identified in the first few steps of the code. Then all the indications associated with that station are transmitted during the rest of the indication cycle.

The first step is always used for lockout to give priority to control transmission. The character is always a Space for an indication code. The character in this step is determined by the control office. If the office accepts an indication transmission, it makes the first step a Space. If a control is to be transmitted at the same time, the first step is a Mark, and the indication cycle will be automatically delayed to permit the control to be received at the field location. The succeeding steps are used to identify stations and define the indications.

The number of steps used to identify stations depends on the number of indication stations required. For example, if there are four stations, then it will take two steps to identify any one of the four. Three steps will identify eight stations. Four will identify sixteen and so on.

The remaining steps define the indications. For example, if there are 14 steps and 1 is used for lockout and 2 for station identification, then there are 11 left for indications. This means that 11 indications per station can be handled, or a total of 4 x 11 or 44 indications from that field location. The tabulation, Figure 936, shows how the possible number of indication stations and the indications increase as steps are used for identifying stations.

Figure 937, is a typical indication code for a 7-step system. First note that as the system cycles twice, there are 14 available steps.

The first step calls for a Space. The purpose—lockout, to differentiate between a control cycle and an indication cycle.

The second and third steps are used for the station identification. Four stations have been selected as an example. The

Steps	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Code	S	M	S	M	S	S	M	S	S	M	S	S	S	S
Function	Lock out	Station Selection		NK	RK	ATK	LGK	RGK	BTK	CTK	POK	SP	SP	SP

Figure 937. Typical indication code for a 7-step system.

code characters on these steps can be MM, MS, SM, or SS. The next two steps, namely 4 and 5 are used for indicating a switch. A Mark on 4 and a Space on 5 will indicate the switch normal. A Space on 4 and a Mark on 5 will indicate it reverse.

The character of step 6 will indicate the condition of track circuit A. A Space says it is unoccupied. A Mark shows it is occupied.

The next two steps are used to indicate signals. A Space on 7 shows signals governing traffic to the left are at stop. A Mark shows them clear. A Space on 8 shows signals governing traffic to the right are at stop. A Mark shows them clear. And so on.

The SP functions are spares.

CENTRALIZED TRAFFIC CONTROL

SECTION INDEX

Introduction 1000
Control Panel 1000
Elements of cTc Operation 1004
  Non-Coded cTc 1004
  Elements of Coding , ... 1005
    Stepping Principles 1007
    Capacity 1009
Carrier Control Operation 1009

INTRODUCTION

Centralized traffic control,* or cTc as it is generally known, is an original development of the General Railway Signal Company. It was first installed in 1927 from Stanley to Berwick, Ohio, a distance of 40 miles, on the New York Central Railroad.

In practice, a centralized traffic control system is made up of a succession of interlockings, all controlled from a single control machine. Automatic block signals are usually provided on the intervening trackage. Such a system may be adapted to any existing signal installation and may be applied to single or multiple track. The control machine, located in an open office within, adjacent to, or remote from the installation, provides means for initiating the desired controls and for displaying the indications which keep the operator informed of train movements and track conditions. Important switches and crossovers are usually power operated to expedite the movement of trains into and out of sidings, junctions, etc.

CONTROL PANEL

Since the operator of a cTc machine has direct control over many functions previously handled by wayside operators, such indications as will facilitate the planning of train movements and the manipulation of the control machine to direct the execution of those movements with maximum efficiency have

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**In 1950, the Interstate Commerce Commission broadened the term to "traffic control system" defined as "a block system under which train movements are authorized by block signals whose indications supersede the superiority of trains for both opposing and following movements on the same track."*

been incorporated in the control panels. In fact, the usual cTc machine provides more complete information, automatically and quickly, than would be possible with wayside operators.

Individual controls are provided for all power-operated switches (and, if desired, all electrically locked hand-operated switches) and for all interlocked signals, that is, signals located at controlled points such as ends of sidings, crossovers, junctions, etc. The automatic block intermediate wayside signals located between controlled points operate inherently as a part of the system, but their individual controls are simply field circuits, arranged for automatic operation. Other wayside facilities such as employee call devices, switch heaters, tunnel door locks, etc. may be placed under the control of the cTc operator if desired.

Figure 1001 shows a typical panel of a cTc control machine. Above the panel is a supplementary track diagram which shows car capacity of sidings, lengths of intermediate tracks, and other information helpful to operation. At the top of the control panel are engraved the names of the controlled points or sidings. Below these and above the track diagram are located the power-off lights, one for each controlled point or field location. These lights are normally dark. When steadily illuminated (red), a light indicates that the a-c. power is off at that location. If the installation is coded cTc, the light will be lighted throughout the duration of an indication cycle from the field location. Should the a-c. power be off and a light is burning steadily, then it will be extinguished for the duration of an indication cycle from its respective field location. This feature keeps the operator informed as to power conditions at the field location and also enables him to readily identify the field location sending in an indication. Both are valuable in event of an operating abnormality.

Next is the engraved track diagram, laid out in geographic

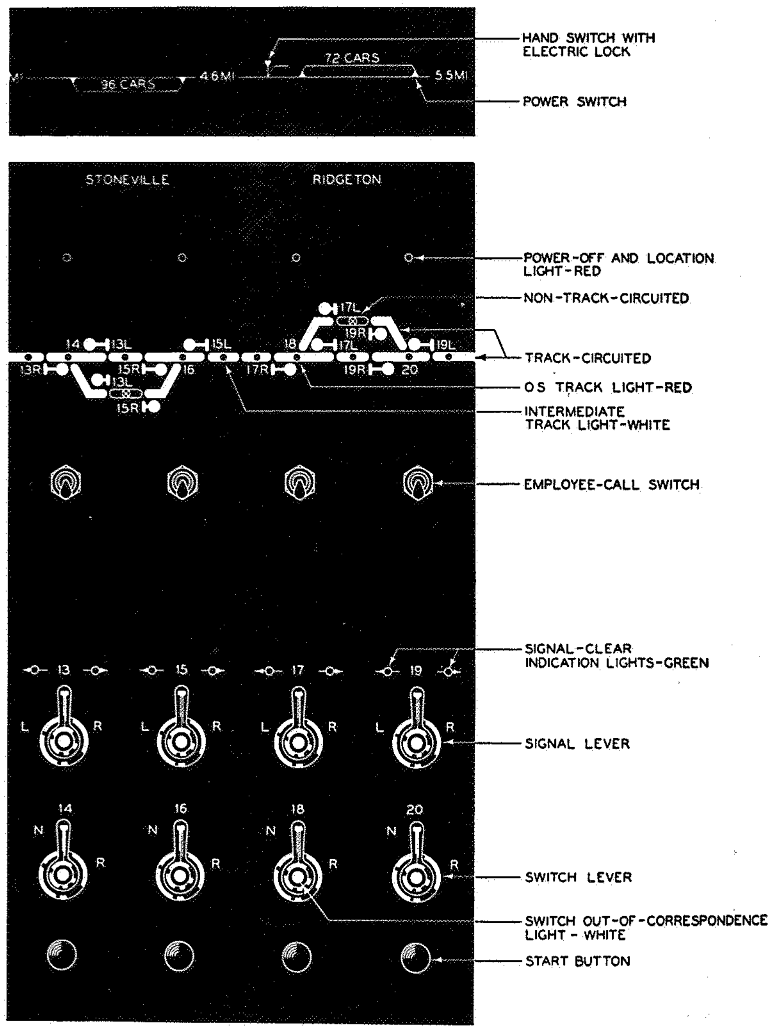
96 CARS
4.6 MI
72 CARS
5.5 MI
HAND SWITCH WITH ELECTRIC LOCK
POWER SWITCH
STONEVILLE
RIDGETON
POWER-OFF AND LOCATION LIGHT-RED
NON-TRACK-CIRCUITED
TRACK-CIRCUITED
OS TRACK LIGHT-RED
INTERMEDIATE TRACK LIGHT-WHITE
14
13L
13R
15R
13L
15R
15L
16
17R
18
17L
19R
17L
19R
20
19L
EMPLOYEE-CALL SWITCH
13
15
17
19
SIGNAL-CLEAR INDICATION LIGHTS-GREEN
L
R
SIGNAL LEVER
14
16
18
20
N
R
SWITCH LEVER
SWITCH OUT-OF-CORRESPONDENCE LIGHT - WHITE
START BUTTON

Figure 1001. Typical control panel.

representation of the territory controlled. Adjacent to it are signal symbols with identifying numbers and the number or name of the switch or crossover or other controlled facility. Within the track line itself are located the track-occupancy indicating lights for different sections of track circuited track. For sections not track circuited, token holes are provided so that the operator may post pertinent information. For example, a work train or a damaged car may be on a non-track-circuited siding. By posting a token bearing the train number or the word "cripple," he can keep himself and other operators informed of this condition. White lights are generally provided for approach and intermediate track sections and red lights for the "OS" track sections (detector track sections within controlled points). These lights are normally dark and are illuminated during track occupancy or in event of a broken rail or any other condition that causes the track relay to open its front contacts. An audible signal, bell or buzzer, may be provided to work with the OS lights or important approach lights. These are usually arranged to sound momentarily at the time the track-occupancy indication is first displayed.

Below the track diagram are the employee-call switches, usually one for each controlled point. Such a device (at the field location) may be a horn, ringer or light, or a combination thereof. The switches controlling such devices are two-position, on and off.

Next are the signal-clear indication lights, two for each signal lever. These indications are directional, that is, the light representing the signal governing movements in one direction will light when the corresponding signal is clear in the field.

Next are the signal levers, which are three-position rotary switches. Their normal position is center (vertical) which calls for the corresponding group of signals to display their stop aspects. Turning a lever to the right calls for a signal governing movement toward the right to clear; to the left, for a signal governing movement toward the left. Where two or more signals govern in the same direction, selection of the one to clear is a field function, controlled by local signal selection circuits taken through switch-repeater relays. cTc controlled signals are usually arranged for stick operation, that is, they are automatically put to stop upon acceptance by a train. They will remain at stop until again cleared by the operator. Non-automatic operation may be provided if desired.

Below the signal levers are the switch levers, one for each switch or crossover associated with the signals governed by the lever above. These levers are also rotary switches, normally two-position as shown, having the vertical position as normal. Turning 90 degrees to the right calls for the switch reverse. Engraved letters N and R show normal and reverse positions.

Each rotary switch used in G-R-S control machines is designed to accommodate a lamp in its barrel which, when lighted, shines through a translucent insert. This is known as the switch-correspondence light. When lighted, it indicates that the switch or crossover in the field is not in correspondence with the position of its controlling lever. Some roads prefer to use this lamp to indicate that the associated switch is electrically locked in the field. In such case, the switch-correspondence light is located in the panel directly underneath the lever.

At the bottom of the panel are shown the start buttons, ordinarily used only if the cTc system is coded. When controls are to be sent out, say for example, to reverse switch 18 and clear signal 17R at Ridgeton for a train to enter the siding, the operator turns signal lever 17 and switch lever 18 to the right. Then he pushes the start button directly below these levers. The transmission of the controls to the field will not begin until after the start button is pushed. The control message, received and deciphered in the field, will ask for switch 18 to reverse and then for the lower unit on signal 17R to clear, indicating that a diverging route is set up. The execution of these controls will, of course, be subject to the local interlocking circuits at the location, including detector locking, approach locking, track and block conditions, etc.

At the time switch lever 18 is turned to the right, the switch-correspondence light in the barrel of the lever is lighted, indicating to the operator that the switch in the field is not in correspondence with the position of the lever. This light remains lighted until an indication message is received in the control office to the effect that the switch is over (reverse) and locked. When an indication message is received to the effect that signal 17R has cleared, the signal-clear indication light above and to the right of signal lever 17 is lighted.

The foregoing control panel description is of an assumed typical panel. Variations according to the individual railroad's preference may be made. For example, some roads prefer one lamp in the barrel of the signal lever to indicate signal-clear, whether right- or left-hand signal, instead of the two directional signal-clear indication lamps shown. Another feature sometimes provided is a lock light for each switch lever. This lamp may be carried in the barrel of the switch lever, with the switch-correspondence lamp located directly below the lever, or vice versa. When lighted, the lock light indicates that the switch is electrically locked in the field and will not respond to controls asking for a change in its position. Signal and switch levers may be transposed, the switch above and the signal below. Switch levers may be three-position, arranged to call for the switch reverse with lever horizontal to the right or to the left. In this way, if a train movement is to be made toward the right, all levers being positioned (other than normal) for such a move may be positioned toward the right; if to the left, all levers would point left. Another pushbutton may be added to be operated in conjunction with the signal lever when a non-automatic (call-on) signal is to be cleared. Such an arrangement insures against the displaying of such an indication except when deliberately executed by the operator.

Local field circuits may be arranged for either of two basic schemes of cTc operation: with or without preconditioning. With preconditioning permitted, the controls required to change a route for a second train may be transmitted to and stored at a field location in preparation for the second train while a first train is occupying a conflicting route. With this arrangement, the stored controls will automatically change the route as soon as the locking circuits are released by the departure of the first train. This means that with preconditioning, controls can be initiated by the operator to line up the second route as soon as indications on the control panel show that the first train has occupied the first route.

Sometimes exit lights are incorporated in the control machine. Exit lights assist the operator in readily determining if he has lined up the desired route in its entirety before he pushes the start buttons and sends the controls to the field for execution. This is of particular value for layouts where a number of possible routes diverge from any given entrance point. When the operator desires a certain route, he first positions all required switch and signal levers. At this time an exit light will be lighted at the point on the engraved track diagram showing the point to which his route lineup leads or, in other words, at the point where the train will exit. He is thus assured that he has positioned all levers properly and may then push the required start buttons to begin the transmission of the controls to the field.

If the system is coded cTc, a succession of controls may be initiated on the control panel at one time. The system will store such initiated controls and release them, one at a time, for transmission to the field in rapid succession without further attention on the part of the operator. Any controls so stored, awaiting their turn to be transmitted, may be cancelled by the operator, if desired.

If it is considered necessary to verify the indications from any field location, a recheck switch provided on the control machine's master panel may be operated in conjunction with the start button for the particular field location. By means of this facility, a complete check of the indications from a field location may be made without disturbing any of the field functions, that is, without changing the position of a switch or the indication displayed by a signal.

If some abnormal condition at one of the field locations causes that station to repeatedly transmit indications into the control office and thus occupy the line to the exclusion of other stations, a "field cancel" switch provided on the power and test panel of the cTc machine may be manipulated, and the impaired field location will be made to retire and free the line.

A facility often added to machines controlling extensive territories is an automatic train recorder. The recorder may be installed as an integral part of the control machine. Records of train movements are automatically made on a constantly moving chart, which is marked with time graduations. The chart is also provided with location identifying lines by means of which the various siding ends, crossovers, junction points, etc., may be identified. Provision is usually made to record the occupancy by a train of each OS track section in the territory. Signal-clear or other desired information may be recorded if desired. The operator, at his convenience, may connect all recording marks made by a train, and in this way the chart becomes a graphic train sheet.

Space for telephone, telegraph and other desired apparatus may be provided in the control machine as required. Telephone communication circuits are often combined on the cTc control line with the code circuits. Such facility may be supplemented with the employee call facility, generally provided for use when the operator desires to call a particular field location, and by a voice-actuated call device which will audibly signal the operator when parties call from the field.

In brief, any practical control machine arrangement or operating facility may be incorporated in a G-R-S cTc system.

ELEMENTS OF cTc OPERATION

Detailed description of an actual cTc circuit would take far more space than is available in a book of this nature. What are described here are elementary principles of operation. For details of a particular system, refer to the appropriate G-R-S handbook as listed in the bibliography at the end of this section.

NON-CODED cTc

In this elementary circuit, Figure 1002, note the line circuit in which a three-position control lever, a neutral indication relay, a polarized relay, an OS track relay contact, and a switch repeater relay contact are all connected in series. The track relay contact and the switch repeater relay contact are used to control the indication relay.

This basic line circuit is duplicated to each field location. It performs four important functions: (1) controls the switch to normal or reverse, (2) controls the signal to stop or clear, (3) indicates the switch in transit, and (4) indicates track occupancy.

The eastbound train is approaching the siding and the operator intends to direct the train into the siding at Luckey. Throwing the three-position lever 1 upward polarizes control relay 1, and the switch operates to the reverse position. The

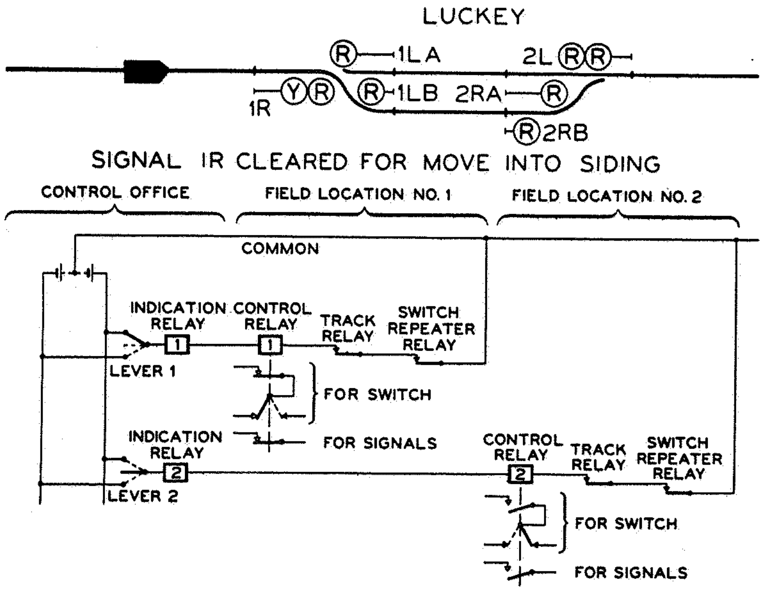
LUCKEY
1LA
2L
1R
1LB
2RA
2RB
SIGNAL IR CLEARED FOR MOVE INTO SIDING
CONTROL OFFICE
FIELD LOCATION NO. 1
FIELD LOCATION NO. 2
COMMON
INDICATION RELAY
CONTROL RELAY
TRACK RELAY
SWITCH REPEATER RELAY
LEVER 1
FOR SWITCH
INDICATION RELAY
FOR SIGNALS
CONTROL RELAY
TRACK RELAY
SWITCH REPEATER RELAY
LEVER 2
FOR SWITCH
FOR SIGNALS

Figure 1002. Elemental principles of unit-wire cTc.

lower arm of signal 1R assumes the yellow aspect, being controlled through the neutral contact of the control relay and detector contacts of the switch machine.

When the train accepts the signal and moves into the siding, it shunts the OS track section, thereby releasing the track relay. This deenergizes indication relay 1 in the office which, in releasing, lights the track occupancy light on the panel (this part of the circuit is not shown).

When the operator is ready to let the train proceed out on the main line, he raises lever 2 controlling the switch and signals at field location 2. This action reverses the switch. Dwarf signal 2RB will clear after the switch completes its movement and permit the train to enter the main track.

While this first train was in the siding, the operator could have directed a faster train to move past the siding in either direction on the main line.

Of course, additional refinements are incorporated in the practical application; such as, signal stick, signal selection (both direction and route), both approach and detector locking of the switch, and others as desired.

From the signal circuit point of view, cTc is a communication system whereby the man at the control machine can directly impress a supervisory control over the orthodox and time proven signaling elements—track circuit control of signals, automatic block, and all the types of locking that have been developed for safety of operation, with all safety features incorporated in the field between the functions. These circuits are shown in the section on interlocking.

This non-coded cTc system requires a separate control wire to each location and a common wire to all locations. It is obvious that the amount of line wire increases very rapidly as the number of functions to be controlled and the length of the installation increase. As a result, new schemes have been developed which reduce the amount of line wire and increase the transmission distances. Such systems are known as "coded" cTc.

ELEMENTS OF CODING

The basic object of the coded systems is to transmit the controls and indications between the control office and the field locations over a minimum number of line wires by a series of relatively short current pulses, arranged in code formation. This is distinctive from the sustained energization or deenergization of numerous, separate line circuits. Outbound controls and inbound indications share the same line wires, using them only for short periods of time.

Figure 1003 is a simplified, elemental scheme which illustrates the basic principles of a coded system. Imagine that there is a step-by-step device at the control office and another at the field location. Also, imagine that they are capable of being so synchronized that arms A and B can be moved simultaneously to make contacts 1, 2, and 3. At the office, levers L1, L2, and L3 are connected to contacts 1, 2, and 3. At the field location, polar relays R1, R2, and R3 are connected to contacts 1, 2, and 3 and may be used to govern the operation of switch machines, wayside signals, etc. The lever contacts are connected to a split battery, the common wire of which is connected to all three relays in the field.

Assume the step-by-step devices are set in motion, stopping for a moment when arms A and B touch contacts 1. Now if lever L1 is placed in the down position, relay R1 will change and its neutral contacts, not shown, will close.

When the devices move to position 2, lever L2 is connected to relay R2, but this relay will not operate to call for a change in its controlled functions since lever L2 was not changed.

On step 3, lever L3 is connected to relay R3, and the stepping

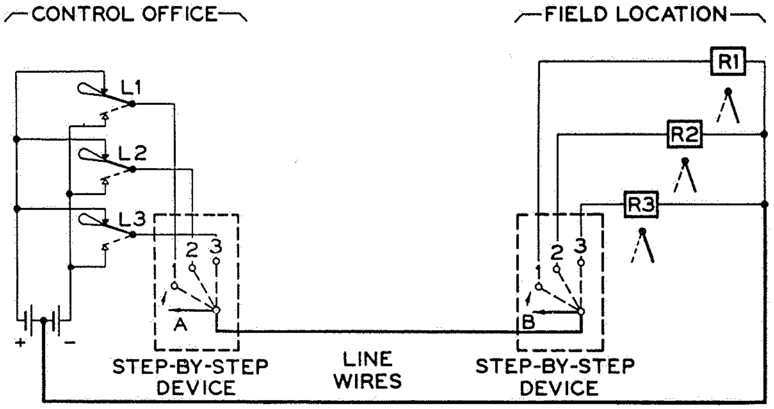
CONTROL OFFICE
FIELD LOCATION
L1
L2
L3
1
2
3
A
+
-
STEP-BY-STEP DEVICE
LINE WIRES
STEP-BY-STEP DEVICE
B
R1
R2
R3

Figure 1003. Elemental principles of coded cTc for one field location.

cycle is complete. At this point the step-by-step devices could be restored to their original position ready to start the cycle all over again when a new control is to be sent out.

It should be understood that a "control" is the action necessary to operate a two-position field function or device, such as a polar relay. Also, an indication is the action necessary to describe the condition of a two-position field function or device, such as a track relay.

Figure 1004 is another elemental diagram having two field locations. It shows how one location is selected from among many.

Levers L1, L2, and L3 are to control relays R1, R2, and R3 at location 1, and levers L4, L5, and L6 are to control relays R4, R5, and R6 at location 2. Again there are synchronized stepping devices, one at the control office and one at each field

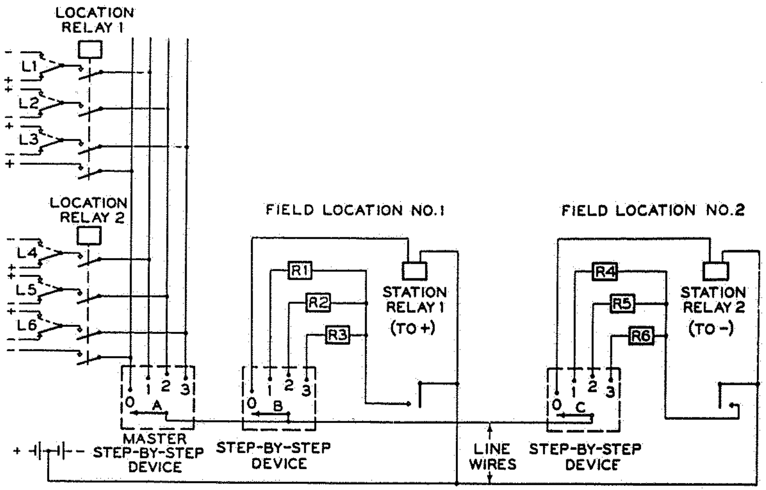
LOCATION RELAY 1
L1
L2
L3
LOCATION RELAY 2
L4
L5
L6
FIELD LOCATION NO.1
FIELD LOCATION NO.2
R1
R2
R3
STATION RELAY 1 (TO +)
R4
R5
R6
STATION RELAY 2 (TO -)
0 1 2 3
A
B
C
MASTER STEP-BY-STEP DEVICE
STEP-BY-STEP DEVICE
LINE WIRES
STEP-BY-STEP DEVICE

Figure 1004. Elemental principles of coded cTc for two field locations.

location. When the arm on the master device moves to contact O, the other synchronized devices do the same.

One step is used to select the location. The O contact of the master device is connected to plus or minus through a front contact of location relay 1 or 2, depending on which relay is energized. The O contacts of the field step-by-step devices are connected to the station relays.

The basic principle of selecting the right location to which to send controls is to apply the proper polarity on the line when the arms touch the O contacts. This will cause the proper station relay to close its contact and connect the control relays to the line for the controls that follow.

Assume the operator desires to send controls to location 2. When he presses the code start button on his panel, location relay 2 is energized. Note how minus polarity is connected to contact O on the master device, so that when all the movable arms touch the O contacts the station relays at both locations are polarized to the right. The polar contact closes at field location 2, but remains open at field location 1. Location 2 is thus automatically selected.

The next step, with contacts 1 closed, is similar to the action described for a single location. The desired field location having been selected, lever L4 is connected to relay R4. On step 2, lever L5 is connected to relay R5, and on step 3 lever L6 is connected to relay R6. In positions 1, 2, and 3, the positions of the levers determine the positions of their respective relay contacts in the field.

In actual practice the basic schemes shown in Figures 1003 and 1004 are substantially amplified as follows:

1. Banks of stepping relays perform the function of the step-by-step devices.
2. Sensitive line relays respond to line circuit energizations and control operation of other relays by local batteries.
3. Other relays and circuits are added to provide starting of the transmission cycles, station selection and registration, and other standard and special features.

Stepping Principles

It has been noted that the step-by-step device must be capable of being synchronized accurately with similar devices remote from it. Several methods were developed, some with rotary switches like the wipers used in telephone exchanges. Then the all-relay type of stepping was developed and has been used extensively because of its dependability. The basic principles of this type will be described, with the understanding that it is only one of several ways that all-relay stepping can be accomplished.

Referring to the simplified circuit in Figure 1005, the control office and field locations are connected by two line wires which join the F relays in a continuous circuit so that when energy is applied to the line circuit all F relays are energized.

The stepping circuits are shown for a field location only, for simplicity. They are practically the same in the control office, and, of course, would be the same at each field location in the system.

As far as the stepping action is concerned, it makes no difference whether the code pulses on the line are distinguished from one another by polarity or by their length. Therefore, although the circuit shows a polar line relay for the stepping circuits in the field, a neutral repeater of the F relay, called FA, is used to actuate the stepping.

The SA relay is a repeater of the FA and is used to apply energy to the stepping circuits. Because it is slow-release it remains picked up during the short intervals when the line is deenergized between pulses, known as OFF periods. At the end of a complete cycle, the SA relay releases. Its function then is to remove energy from the stepping relays and restore them all to their original position, ready for the next cycle. In effect it returns the movable arm of the step-by-step device to the starting position. The rest of the relays, the V relays, are concerned with the stepping action, and therefore constitute the relay equivalent of the step-by-step device.

The operator starts the action by pressing the start button. The cycle begins with a "conditioning period," when certain relays are prepared to transmit and receive. The line is energized, as are also the **F** relays. The **FA** relay and the **SA** relays in both office and field pick up, followed by the **VP** relay. Upon picking up, the **VP** causes the line circuit to open at the office, thus ending the conditioning period.

The opening of the line starts the first **OFF** period. The **F** relays and the **FA** are deenergized. However, the **SA** remains picked up, since it is slow-release. Therefore, relay **VI** will now pick up, through a back contact of V2 to make certain the stepping proceeds in proper sequence. Once V1 relay is picked up, it remains up for the rest of the cycle by a stick circuit through a front contact of the **SA** relay.

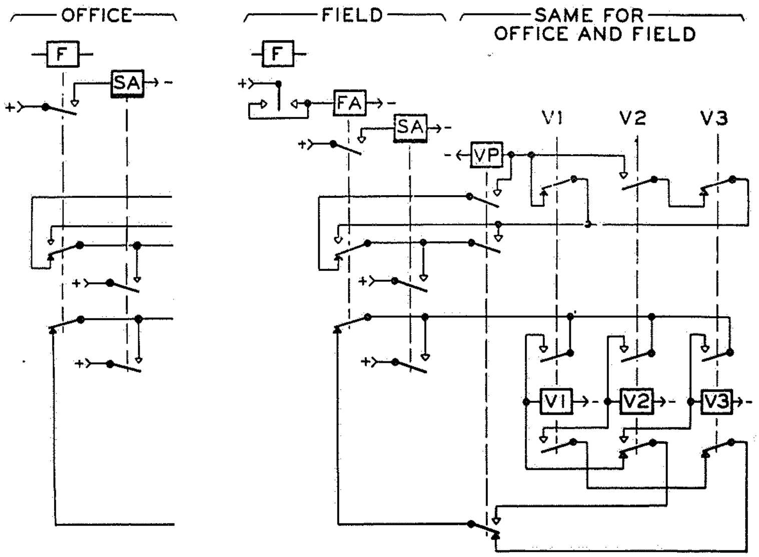

Figure 1005. Stepping circuits.

At this point all the V1 relays are up, at the control office and all field locations. This is the equivalent of closing contact 1 on all step-by-step devices.

During the first **OFF** period, the **VP** relay is held up by a stick circuit through a front contact of **SA** relay and a back contact of **FA**.

As soon as the V1 relay in the office picks up, the line is again energized, thus starting the first **ON** period. Both **F** relays are energized. The **FA** relay picks up and reenergizes the **SA**. The stick circuit to **VP** relay is opened and **VP** releases. This, as before, causes the line circuit to open at the office, thus ending the period.

The second **OFF** period is now started. The **F** relays and the **FA** are deenergized, but the **SA** stays up because it is slow-release. The V2 relay now picks up, checking that V3 is released and V1 is picked up. All V2 relays are thus picked up all along the line, the equivalent of closing contact 2 on the step-by-step devices.

When V2 relay in the office picks up, the line circuit is again energized, starting the second **ON** period. Again both **F** relays, the **FA** and the **SA** are energized. The **VP** relay picks up through a back contact of V3 and a front of V2 relay, checking their proper position in the cycle.

When **VP** picks up, the line circuit opens at the office, starting the third **OFF** period—and so on, until the system steps through the entire cycle and the last step relay is picked up. At this point the line is deenergized and remains deenergized long enough to cause the slow-release **SA** relay to release and restore all the step (V) relays to normal.

The number of step relays in a system depends upon the number of controls or indications to be transmitted, and the number of field locations to be selected.

Capacity

In the simplest form, each step can be considered as a channel on which either of two things can be done to provide character.

In such a system, the capacity in stations is 2 to the nth power, where n is the number of steps used in the station selection portion of the code. That is, 2 selections on 1 step, 4 on 2 steps, 8 on 3 steps, and so on

The common siding end location requires 3 steps for controls:

1. Switch normal—switch reverse.
2. Signal left stop—signal left clear.
3. Signal right stop—signal right clear.

There is often an additional switch or other control, such as a maintainer's call required. Therefore, 4 steps are generally allocated for controls.

Recently, high-speed coded systems have been developed using electronic stepping techniques and line currents of carrier frequencies that enormously increase the speed and capacity of coded control systems.

CARRIER CONTROL OPERATION

It is often desirable or necessary to divide a large centralized traffic control territory into two or more sections, each handled independently from the same control office. This would ordinarily require a separate pair of line wires for each cTc section.

However, by means of the G-R-S carrier control system, only one pair of line wires is required for the whole territory. Carrier control consists of providing carrier-frequency currents that act as a connecting link between a control office and one

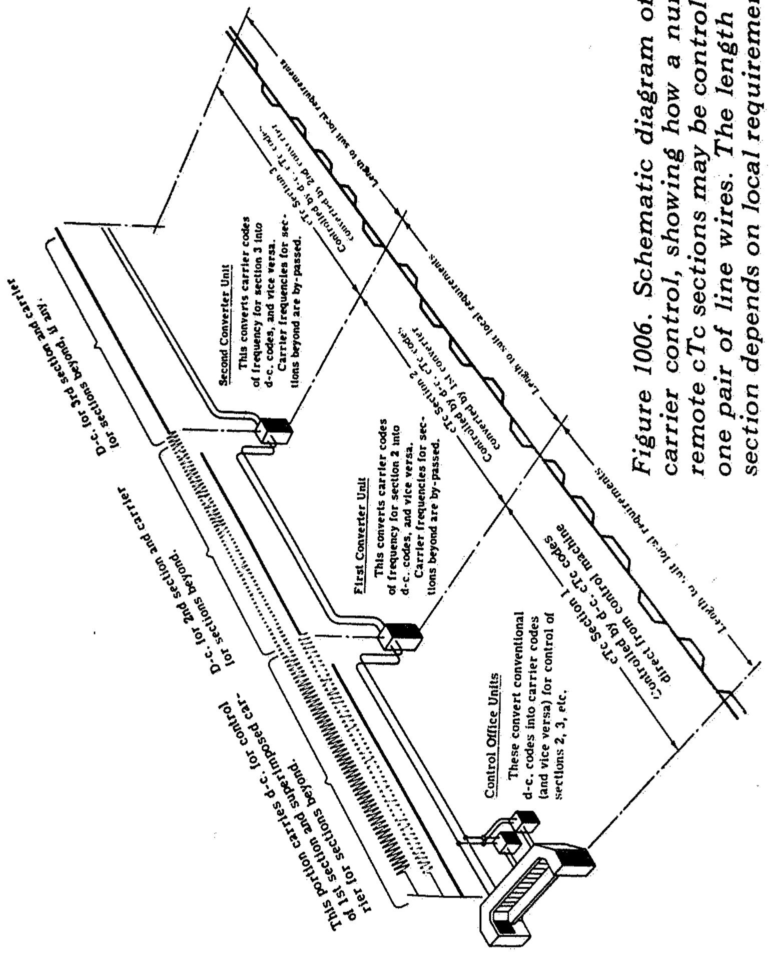
This portion carries d-c. for control of 1st section and superimposed carrier for sections beyond.
D-c. for 2nd section and carrier for sections beyond.
D-c. for 3rd section and carrier for sections beyond, if any.
Second Converter Unit
This converts carrier codes of frequency for section 3 into d-c. codes, and vice versa. Carrier frequencies for sections beyond are by-passed.
First Converter Unit
This converts carrier codes of frequency for section 2 into d-c. codes, and vice versa. Carrier frequencies for sections beyond are by-passed.
Control Office Units
These convert conventional d-c. codes into carrier codes (and vice versa) for control of sections 2, 3, etc.
cTc Section 1 Controlled by d-c. cTc codes direct from control machine
cTc Section 2 Controlled by d-c. cTc codes converted by 1st converter
cTc Section 3 Controlled by d-c. cTc codes converted by 2nd converter
Length to suit local requirements
Length to suit local requirements
Length to suit local requirements

Figure 1006. Schematic diagram of G-R-S carrier control, showing how a number of remote cTc sections may be controlled over one pair of line wires. The length of each section depends on local requirements.

or more remote sections of coded cTc. The first cTc section is usually handled directly from the control office without the aid of carrier. The second section is remotely controlled from the same control office by means of carrier currents superimposed on the line wires of the first section. A third section can be controlled by means of carrier currents of a different frequency superimposed on the same line wires of the first and second sections. Additional sections can be controlled in a similar manner if required.

G-R-S carrier control can also be used to control remotely a complete cTc territory from a control office located some distance from the controlled territory. In all of these applications, simultaneous and independent operation of each of the cTc sections is an inherent feature of the system.

The characteristic pulses of the cTc codes are converted into pulses of coded carrier currents for transmission to and from the control office. At the beginning of each carrier section there is a code unit which converts carrier current impulses into d-c. code impulses and vice-versa for sending back indications to the control office. A similar code unit at the control office converts carrier impulses into d-c. code impulses and vice-versa, for the control of cTc sections beyond the first section.

AUTOMATIC CAR CLASSIFICATION

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  Retarder Control Machine 1102
  Automatic Retarder Control 1103
Automatic Switching 1104
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BASIC ELEMENTS

The G-R-S car classification system provides an efficient, economical method of handling cars in classification yards of the gravity type (hump yards). The particular design of a G-R-S classification system varies from yard to yard, depending upon location, type and weight of cars to be handled, number of tracks, volume of classification work, etc., but basic elements in all installations are electric car retarders for controlling the speed of cars, and power-operated switches for routing cars to classification tracks. Either or both of these elements, retarders and power switches, may be manually controlled or may be automatic in operation, as described later.

ELECTRIC CAR RETARDERS

The G-R-S car retarder, Figure 1101, is a rail brake, electrically controlled, by means of which the speed of cars rolling down to the classification tracks may be regulated, either automatically or manually. The braking effect of the retarder is obtained by means of heat-treated alloy steel shoes mounted on each side of the rails, as shown in simplified form for one rail, in Figure 1103. A reversible motor and an associated gear train (part of the mechanism shown in Figure 1102) rotate the drive gear. Counterclockwise rotation of the drive gear moves the shoes toward each other, as shown by the arrows adjacent to the shoes. Clockwise rotation separates the shoes. To obtain retardation, the shoes are positioned so that the space between them is less than the thickness of a car wheel. When a wheel moves between the shoes, the shoes are forced apart against the compression of the spring. The resultant frictional forces between the shoes and the car wheel serve to retard the car.

The amount of retardation obtained depends upon the posi-

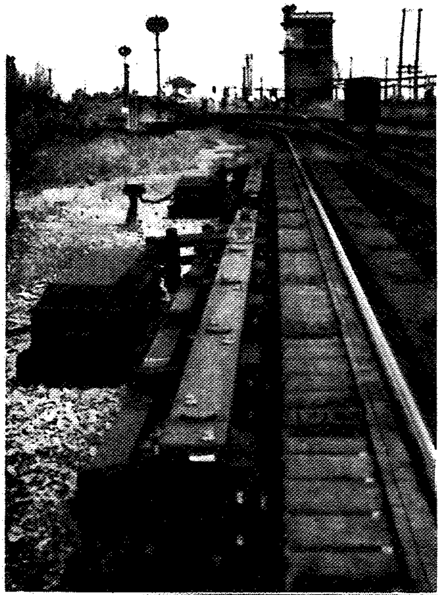

Figure 1101. Electric car retarder. Cases at left house retarder mechanisms.

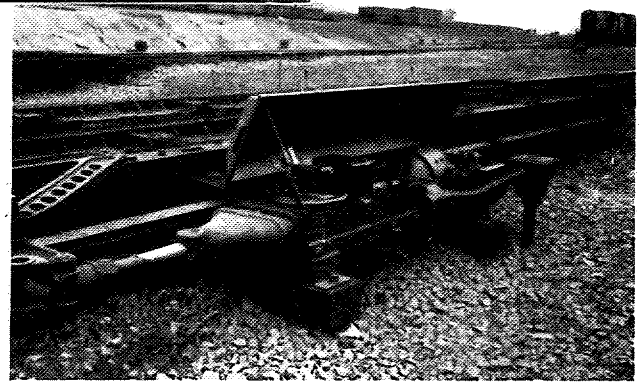

Figure 1102. Car retarder mechanism.

tion of the retarder shoes when there is no wheel between them. The closer together in their original position, the more the spring is compressed when the shoes are separated to car-wheel width, and the greater the braking force exerted by the retarder.

The retarder mechanism usually provides two positions of the shoes, for two degrees of retardation, and an open position in which the shoes do not touch the wheels. In the maximum closed position, the G-R-S retarder is capable of stopping and holding a car on the hump grade; in the open position, the retarder has no effect on the car.

As shown in Figure 1103, a combination of fixed and floating pivots is used to adjust the spacing between shoes, an arrangement which makes the pressure exerted by the shoes equal on both inside and outside surfaces of the wheel. This equalized shoe pressure gives a high average pressure without exceeding the maximum allowable pressure, the point at which a car wheel is lifted. Equalized shoe pressure, regardless of variations in wheel thickness and spacing of wheels on axles, thus permits maximum retardation effect.

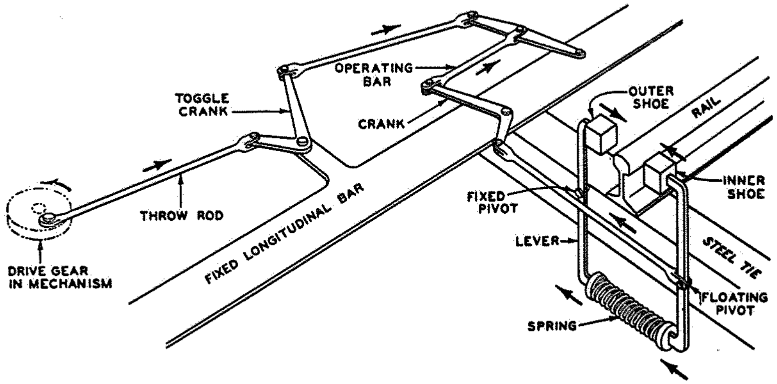
OPERATING BAR
TOGGLE CRANK
CRANK
OUTER SHOE
RAIL
INNER SHOE
THROW ROD
FIXED LONGITUDINAL BAR
FIXED PIVOT
LEVER
STEEL TIE
DRIVE GEAR IN MECHANISM
FLOATING PIVOT
SPRING

Figure 1103. Simplified diagram of linkage to position retarder shoes. Shown for one rail.

Figure 1103 also shows the toggle action which occurs between the toggle crank and the operating bar as the shoes are closed. As a result of this high mechanical advantage, only moderate torque is required of the drive motor, even when compressing the springs directly, as when the retarder is adjusted to a higher degree of retardation with a car in the retarder.

Articulation of the beams which support the retarder shoes permits adjacent springs to share the retardation load and at the same time eliminates the possibility of binding caused by variations in track level. The G-R-S retarder readily adapts itself to considerable vertical misalignment in the track, and, in fact, is frequently installed on vertical curves. Articulation provides the additional advantage that any number of retarder units may be assembled in line to produce a continuous retarding surface with most economical use of track space.

G-R-S retarders are available in units of 5½ feet of rail length, for application to one rail or both, or for combinations of single- and double-rail retardation, and as many as nine units of double-rail retarder (49½ feet) may be operated from one mechanism. For most efficient utilization of a given total length of retarders, and for flexibility of control, a set of retarders is usually located just below the crest of the hump, with additional sets of retarders on the tracks which lead to each group of classification tracks. This arrangement permits preliminary retardation of all cars by the hump retarders, with final control at the retarders located ahead of the classification track groups. A typical retarder layout of this kind is shown in Figure 1104.

CONTROL OF RETARDATION

Since rolling resistance of cars varies with type of car, condition of journals, wheel wear, weight, temperature, wind conditions, etc., the grades in the yard must ensure that the hardest rolling car will roll through the yard to the desired position on a classification track. The retarders must control speeds of the cars so that the freer rolling cars, which would otherwise acquire excessive speed, are sufficiently slowed to enter the classification tracks at proper speed.

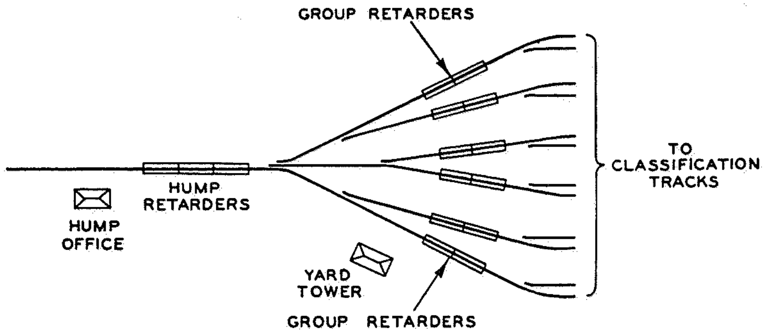

Figure 1104. Typical arrangement of retarders.

RETARDER CONTROL MACHINE

The retarder control machine, Figure 1105, is located in a tower from which the operator has a clear view of the tracks and the retarders. Mounted on an engraved track diagram, the retarder and switch control levers are positioned in the same relation to each other as are their corresponding units in the yard. For manual control, the retarder levers have three positions: H (heavy) for maximum retardation, L (light) for retardation of light cars, and O for open. With automatic retarder control, there is a fourth position, A (for automatic), described later.

Each switch lever controls its switch under direct manual control when it is aligned with the track diagram. It is placed in the off-the-track position for automatic switching control. A red indicator light in the barrel of each switch lever shows up when the track circuit at the switch is occupied. An opal indicator light in each diverging track near each switch shows how the switch is lined up.

Sockets are provided at each switch lever for receiving locking pins so the operator can lock the lever into position, either off the track for automatic switching or aligned for a certain track. One purpose is to provide blue-flag protection by switching cuts away from the affected track. On some installations, there are sockets provided on the diagrammatic track layout, one at the end of each classification track. Inserting a locking pin into one of these sockets prevents the switch from operating to switch a car onto the blue-flagged track.

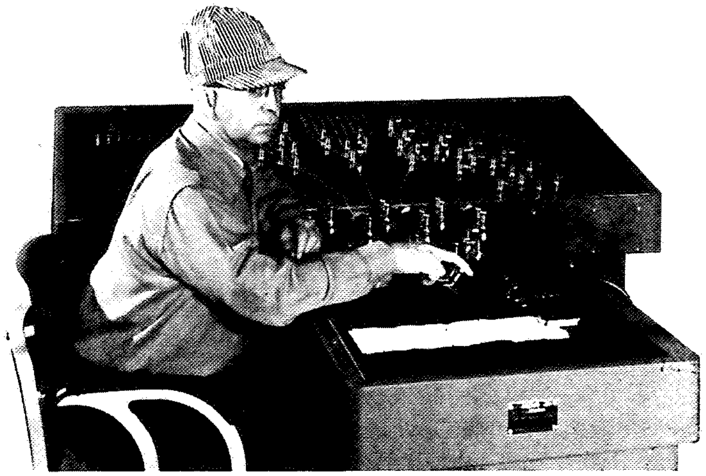

Figure 1105. Located in a tower overlooking the yard, the retarder control machine has controls for retarders and provides for manual control of switches when necessary.

An amber clearance light is also placed at the end of the track diagram for each classification track. Normally dark, these light when a car is moving over the fouling section, thus lighting up and going out again as each cut rolls into the classification track. A steady light warns the operator that a car is fouling the switch and that he should manually line switches to avoid a collision.

AUTOMATIC RETARDER CONTROL

When retarders are equipped for automatic control, there is an additional control lever position, A (for automatic), besides the H, L, and O positions just described. With retarder control levers in the A position, human judgment is replaced by instantaneous electronic calculating circuits, and retardation is automatically adjusted to release each car from each retarder so that the car enters its classification track at the proper speed. Slight modification of the automatic control may be provided by an additional three-position lever that provides for slightly slower or slightly faster than normal releasing speed. At any time, the operator can, by moving his lever from the automatic position, reestablish manual control at H, L, or O positions.

Automatic retarder control requires means for informing the system as to the weight classification of each car. It must also determine the speed of each car while the car is in a retarder.

The weight detecting unit, Figure 1106, is arranged so that the car wheels depress its lever, compressing an internal spring and operating contacts to indicate the weight classification of the car—light, medium, or heavy.

Speed of each car while it is in a retarder is measured by an interferometer, an ultrahigh-frequency transmitter-receiver unit, Figure 1107. Ultrahigh-frequency waves from the transmitter antenna are beamed at the approaching car. The waves reflecting back from the car to the receiving antenna are changed in frequency to a degree dependent upon the speed of

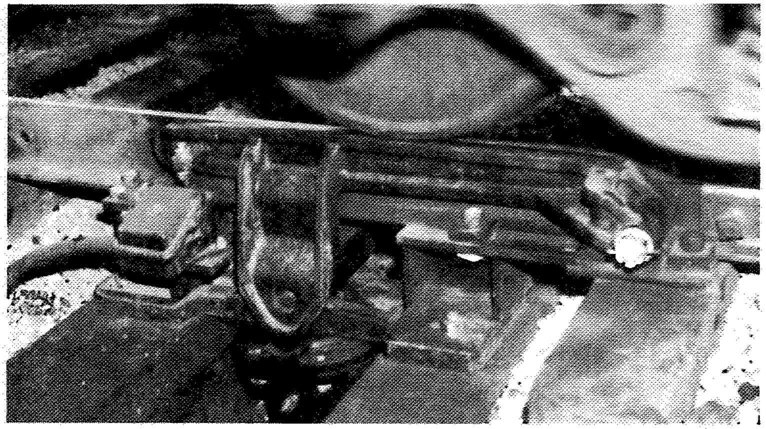

Figure 1106. Car wheel passing over weight detecting unit.

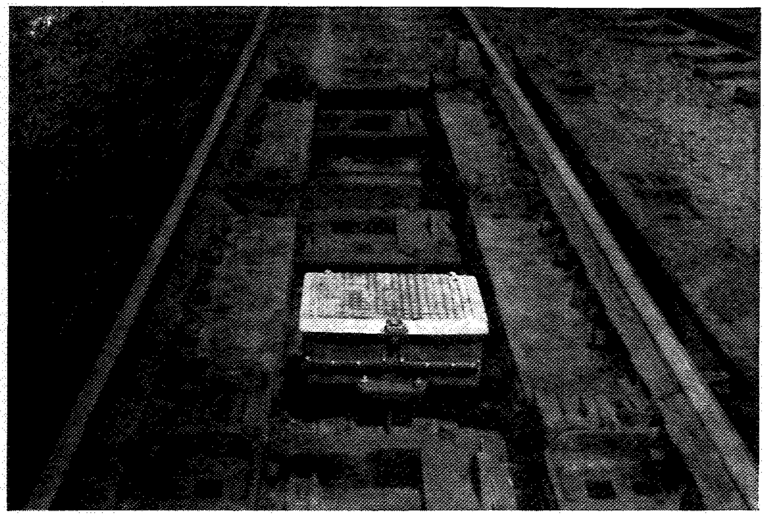

Figure 1107. Original installation of interferometer, a device to measure speed of cars in retarder.

the car. By comparing the frequency of the reflected wave with that of the transmitted wave, the interferometer accurately, instantaneously, and continuously detects the speed of each car while it is in a retarder.

With weight and speed data thus made available, the automatic retarder control system performs calculations with the lightning rapidity so characteristic of electronic "brains." Answers are fed to the retarder mechanisms as controls which apply the right amount of retardation for each particular car or cut of cars.

AUTOMATIC SWITCHING

Another important element in the efficient operation of a hump yard is the method by which the routes are lined up from the hump to the individual classification tracks. In yards equipped with the G-R-S retarder system, routes are established by means of quick-acting power-operated switches. In some installations, switching is handled by the retarder operator, who reads the classification track number for each car from a previously prepared list and lines up switches as required with the switch levers on his control machine. This practice is still followed for smaller yards, where one operator can handle retardation of cars and alignment of switches without difficulty. There is, however, a limit to the number of classification tracks for which one operator can efficiently handle both retarders and switches. For large yards, two, three, or more operators, each in a separate tower, may be needed to handle the volume of work.

A more recent development, G-R-S automatic switching for car retarder yards, relieves the retarder operator of the responsibility for lining up switches and lets him concentrate entirely on retarding cars, and this too, as has been described, can be largely automatic. As a result, one operator and one tower are sufficient for yards of practically any size. Moreover, switching errors are reduced. The combined effect of these two factors—a single tower with one operator and reduction in switching errors—is a substantial gain in efficiency.

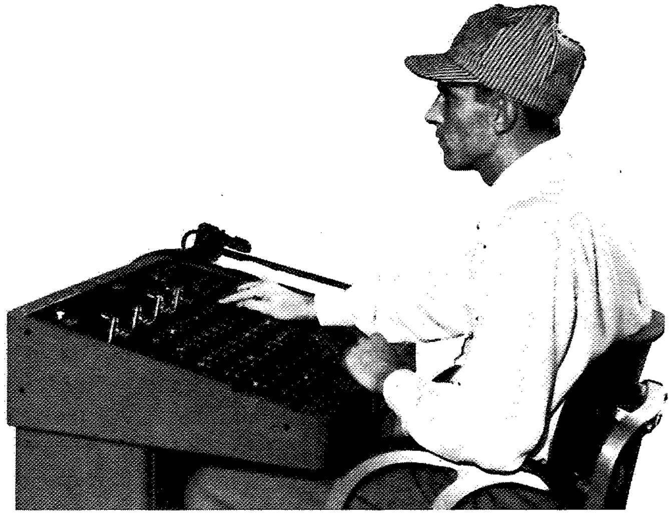

Figure 1108. The hump control machine has a numbered pushbutton for each classification track.

HUMP CONTROL MACHINE

The hump control machine, Figure 1108, has a sloping panel with as many numbered pushbuttons as there are classification tracks. The hump conductor presses the buttons to select the classification tracks for the cars or cuts of cars in the order in which they pass the apex of the hump.

As each selection is made, it is registered into the system by illumination of appropriate numerals on one of four route storage indicators, Figure 1109. The indicators display the selections that have not entered active route development by the occupancy of the first switch track circuit. As each selection is used, the corresponding illuminated number is extinguished and the remaining indications advance one position. Selections may be added in quick succession until all four route storage indicators are lighted; thereafter selection buttons are ineffective until a selection advances into active development.

Should an error in selection be made, pressing a pushbutton marked **CANCEL** will remove the last selection. Repeated pressing of this button will successively cancel all selections that have not started active route development. Another cancellation feature is provided to remove all selections in the system, whether stored or in active route development. This is used primarily to clear the system at the start of humping a train, and is controlled by a button marked **CLEAR SYSTEM.**

Blocking clips, which slip under the pushbuttons, are used for locking out buttons for blue-flagged tracks. While these do prevent operation of the blocked pushbuttons, they are not intended to provide primary protection for these tracks, as this is done on the retarder control machine. They serve only as reminders that another selection must be made if one of the blue-flagged tracks is listed.

The hump signal is also controlled from this panel, by a signal lever which has four positions marked **FAST, SLOW, STOP,** and **BACK UP.** The hump conductor uses this lever to control the movement of trains up the hump. In an emergency, the retarder operator can also set the signal to stop, as his control overrides the hump control.

Likewise the trimmer signal is controlled from this panel with a two-position lever marked **TRIM** and **STOP.** The aspects of the trimmer signal are also repeated on the retarder control machine.

The best operation results from pressing a button when a

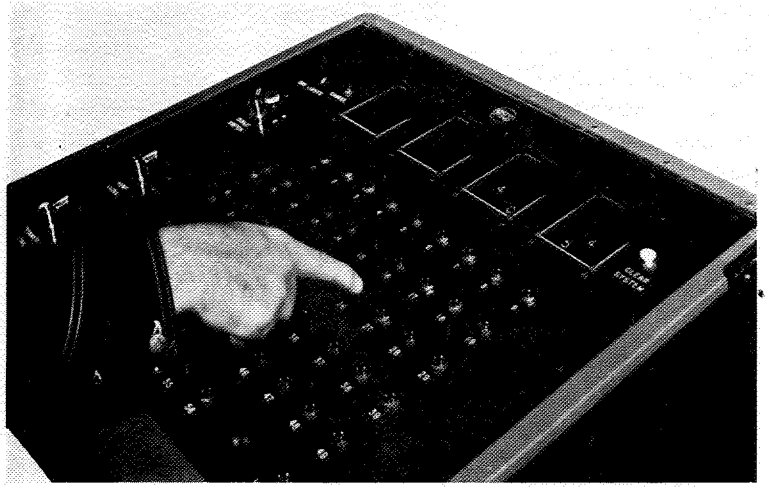

Figure 1109. Route storage indicators on the hump control machine panel show what routes have been stored and in what order.

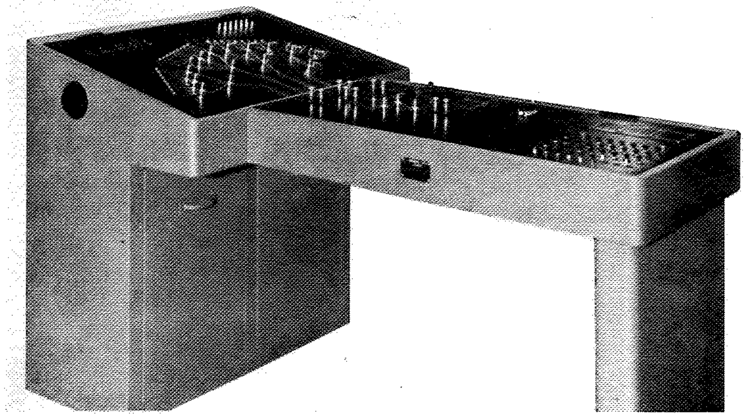

Figure 1110. Combination pushbutton and retarder control machine.

car is cut off rather than filling the storage in quick succession. Storage is provided primarily for the existence of cars between cut-off and route development.

It is customary to install the pushbutton panel for automatic switching in a separate machine, located at the hump, where it is operated by the hump conductor. It is also possible, however, to combine the pushbutton panel with the retarder control machine, Figure 1110, so that the tower operator can handle both routing and retardation.

AUTOMATIC SWITCHING SEQUENCE

Diagrams 1 - 4 in Figure 1111 show a simple switching sequence in a four-track yard served by three switches: A, B, and C. Single-car cuts are going to tracks 1, 3, 2, and 4 in that order.

Diagram 1—The hump conductor presses button 1. Code 1 immediately positions switch A, if it is not already in proper position.

Diagram 2—Car 1 leaves hump and shunts track circuit A. Code 1 positions switch B. Hump conductor presses button 3.

Diagram 3—Car 1 releases track circuit A. Code 3 positions switch A. Hump conductor presses button 2.

Diagram 4—Car 1 shunts track circuit B, then rolls onto classification track 1. Car 3 leaves hump and shunts track circuit A. Code 3 positions switch C.

And so the sequence continues. Note that at the start of the humping, pressing the first button lines up the first switch. Thereafter each car or cut lines up the next switch ahead as it rolls down the hump and shunts each track circuit. The hump conductor merely pushes a track designation button before each cut leaves the hump.

CUTS IMPROPERLY SPACED

What happens if a cut catches up with the cut ahead, as may happen with manual retarder control through some oversight of the operator? The effect, of course, as far as automatic

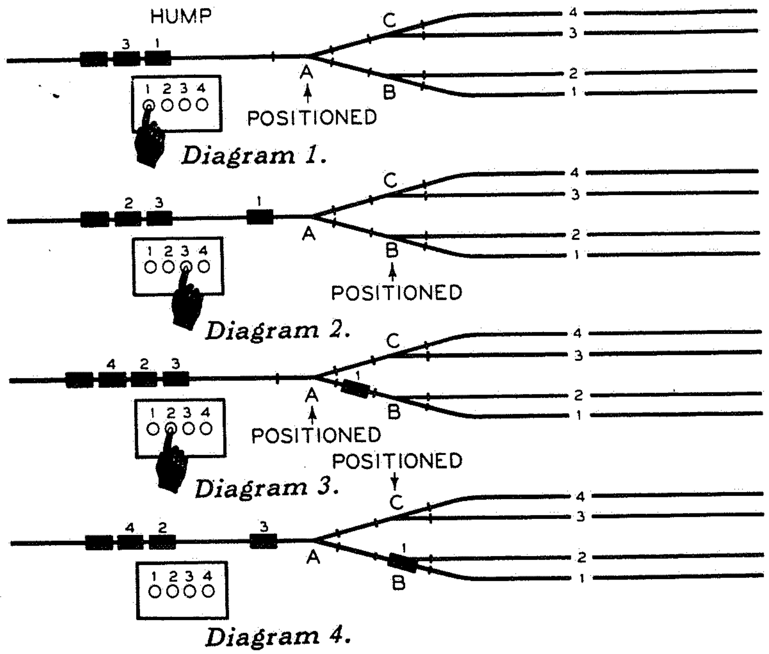

Figure 1111. Automatic switching sequence.

switching is concerned, is to make the two cuts look like a single cut, thus winding up on the same track, which is in all probability not the correct track for the second cut. Also, the code for the second cut, since it was not used, would direct the third cut into the wrong track and all succeeding cuts would be out of step with their codes. To prevent this, code cancelling facilities are provided at each switch. When the retarder operator sees that cut 2 has caught up with cut 1, as indicated by the fact that the red light in the switch lever does not go out between the cuts, and the opal light in the track is still lighted, he merely pulls up the switch control lever at the switch where this occurs. The code for cut 2 is thus cancelled, and code 3 remains in step with car 3. The switch lever returns to its normal position by spring action.

FAILURE OF SWITCH TO LINE UP

Let us assume that a switch is normal and the next code calls for it to go reverse, and an obstruction lodges between the reverse point and the stock rail. The switch machine will crank the point over, meet the obstruction, pause a moment, then return to the normal position. At the same time, a single-stroke bell will sound in the tower, and the red light in the switch lever will start to flash. A corresponding red light on a maintainer's panel will also flash. The cut, of course, will go wrong, but will not be in danger of derailment. The operator would stop humping until the switch is restored to its proper working condition, if other cars in the train are to use the switch.

SWITCH MACHINES

High-speed switch machines, Figure 1112, are used which provide completed switch operation in 0.6 second from the initiation of control. These machines are so constructed that they may be trailed without damage to the machine, switch points, or fittings. After trailing, the switch control lever has to be thrown to correspond to the trailed position to regain control of the switch.

TRACK CIRCUITS

The track circuits, Figure 1113, are the means for passing codes along. They are installed at each switch to prevent throwing the points under a car. The circuits are so arranged, however, that the switch completes its stroke once it starts. The track circuit starts 16 feet ahead of the switch point, a distance which allows operating time at normal car speeds. Each track circuit extends at least 55 feet to prevent spanning by the longest cars.

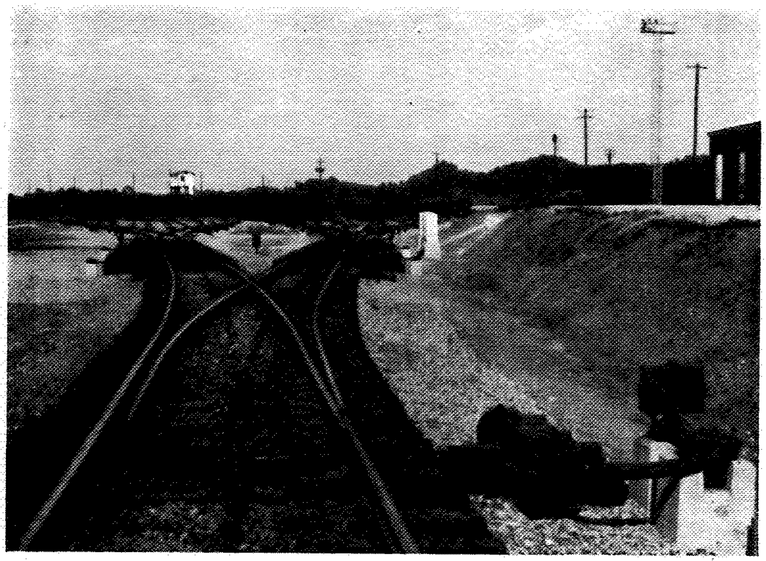

Figure 1112. High-speed Model 6 switch machine and Type P signal.

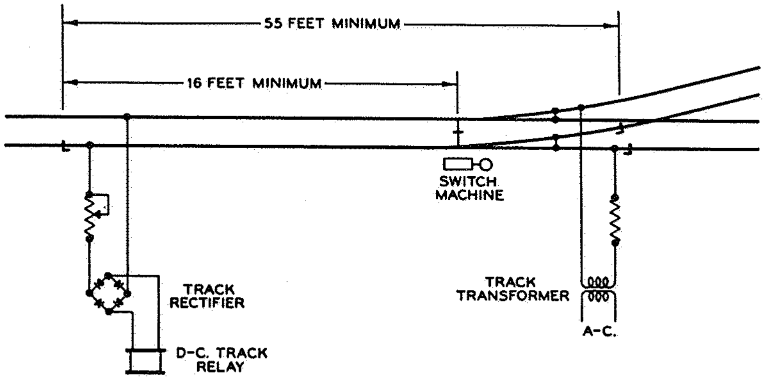

Figure 1113. Track circuit at switch.

SIGNALS

The hump signal produces four aspects, as follows:

Aspect	*Indication*
Green	Hump fast
Yellow	Hump slow
Red	Stop
Flashing red, two reds, or some other aspect	Back up

The trimmer signal has two aspects, as follows:

Aspect	*Indication*
Yellow	Trim
Red	Stop

Hump and trimmer signals are often mounted on the same mast. Normally the control of these signals is interlocked so that both cannot be cleared at the same time.

In order to save time between humping trains, the hump conductor can clear the hump signal to green while the trimmer signal is yellow. This means that the trimmer engine can work while the next train is being pushed toward the hump. There is, however, an approach track circuit to the hump signal. If the trimmer signal is yellow when the train occupies the approach, the hump signal automatically goes to red.

MAINTAINER'S TEST PANEL

On one of the racks in the relay room is the maintainer's test panel, Figure 1114. Code storage indication lights (green for normal and yellow for reverse switch positions) and red track occupancy lights are arranged on the track diagram and give indications similar to those on the retarder control machine. A toggle switch at each turnout enables the maintainer to deenergize the corresponding track relay.

By having someone at the hump set up routes on the hump

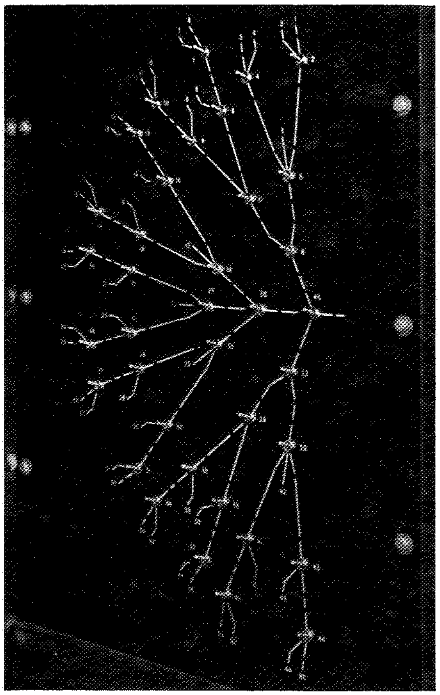

Figure 1114. Maintainer's test panel permits checking operation of the entire automatic switching system in a few minutes.

control machine, and by deenergizing the track relays in sequence by flicking switches on the test panel, the maintainer can give all the automatic switching circuits a functional test in short order. Operation of each switch machine is also checked.

POWER SUPPLY

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BATTERIES

Unless the continuity of operation of the signal system is to depend entirely upon the continuity of the a-c. supply, batteries must be provided. Where there are no a-c. distribution lines, batteries are, of course, absolutely necessary. This section describes briefly the various types of cells. Detailed information on a particular type of cell should be obtained from its manufacturer.

PRIMARY CELLS

A primary cell is a device for the direct transformation of chemical energy into electrical energy. Primary cells are used for feeding track circuits and for operating signals where the ampere-hour consumption is small and where a-c. lines are not practical. Where the load is heavy and where a.c. is available, primary cells are used for standby, often with an automatic rectifier to share the load. Automatic rectifiers are described further along in this section.

There is a great difference in the voltage or current capacity of different kinds of cells. The ordinary dry cell has a voltage of 1.48 volts on open circuit, but if any appreciable amount of current is taken from it, the voltage drops very rapidly. Likewise, the cell recuperates very rapidly on open circuits and will soon be back to its original voltage. The primary cell maintains a quite constant voltage at relatively heavy discharge rates, such as we find in railway signal work.

The voltage of any cell depends on the amount of current that is being delivered by it at the time the voltage reading is taken and the amount of energy that has been taken from it since renewal. If the current drain is light, the voltage may be high; but if the current drain is heavy, the voltage will be greatly decreased.

Copper-Oxide Caustic-Soda Cells

Each cell consists of a positive and a negative plate and a solution in which the plates are immersed. The solution is properly called an electrolyte. An electrolyte is a substance that is a conductor of electric current and that is capable of being decomposed by the passage of current. The electrolyte of the caustic soda cell is a 20% solution of caustic soda (refined concentrated lye) in water. Plates are copper-oxide and metallic zinc. The positive terminal, equipped with thumbscrews, is connected to the copper-oxide plate.

As the cell is used, the oxygen in the copper-oxide plate is used up as is the zinc in the zinc plate, and the cell finally becomes exhausted. Indicator panels built into the plates show, by the degree to which they are eaten away, the condition of the cell.

The capacity of a cell is rated in ampere-hours. One ampere flowing for one hour (2 amps. for ½ hr., or ⅓ amp. for 3 hrs., etc.) is called an ampere-hour.

Theoretical potential of a cell is 1.21 volts. This voltage is, however, never available for use in an external circuit because of the effects of polarization and internal resistance within the cell.

The effect of internal resistance is to cause a sudden drop in voltage as soon as the cell is connected to a circuit. The lower the resistance of that circuit, and therefore the greater the current flow, the greater the drop in voltage at the cell terminals. The theoretical voltage, 1.21, is sometimes called the "potential difference" of the cell to differentiate it from the voltage as read by a voltmeter. A voltmeter reading of as much as 0.90 volt is seldom attained in actual practice. It is maintained for only a very short time after the cell is connected to the load. The voltage of a new cell on open circuit is about 0.95 volt, that of a cell nearly discharged is about 0.75 volt.

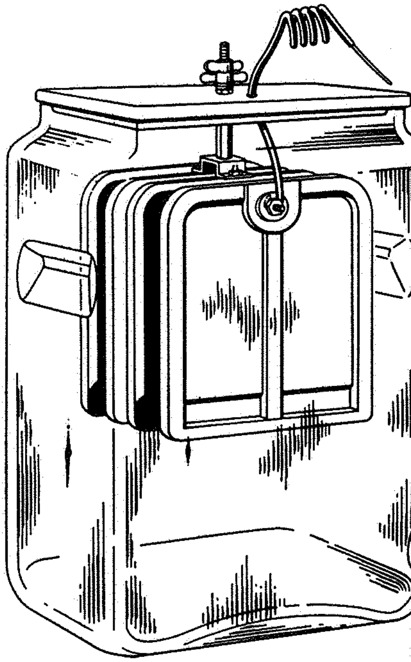

Figure 1201.
Typical copper-oxide caustic-soda primary cell.

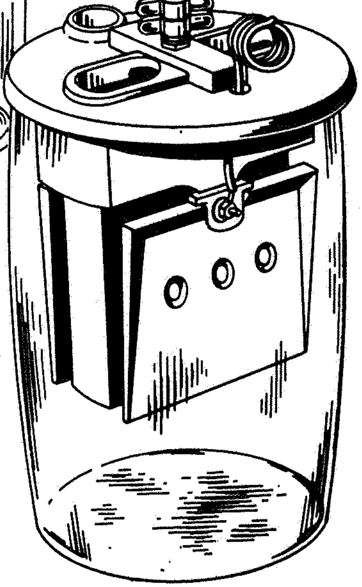

Figure 1202.
Air-depolarized caustic-soda primary cell.

On closed circuit, the voltage varies with the amount of current flow. In track circuit work, the voltage can be safely taken as 0.63. For heavier work, the voltage drops to about 0.5 volt per cell; or in cold weather a good cell may drop as low as 0.4 volt. Low temperatures have the effect of increasing the internal resistance and therefore lowering the voltage on discharge.

There are two general types of copper-oxide, caustic-soda primary cells, AAR Type A and AAR Type B. The type B has an average cell voltage approximately 25% higher than the Type A. This is accomplished by special treatment of the copper-oxide depolarizer.

Air-Depolarized Caustic-Soda Cells

The air-depolarized cell differs essentially from the copper-oxide caustic-soda type in that the cathode is a porous carbon block instead of copper-oxide. This porous carbon is specially processed to render it capable of utilizing atmospheric oxygen for depolarization. For railroad signal service a special design of air-depolarized cell adapted for use in standard AAR glass jars is available as a 500 ampere-hour capacity unit. The construction is similar in its general features to Type A and Type B copper-oxide caustic-soda primary cells, with the exception of the air-depolarizing feature. Operating voltage ranges from about one volt, under heaviest recommended continuous load, to 1.3 volts for light current loads.

LEAD-ACID STORAGE CELLS

The AAR Signal Section defines storage cell as a secondary cell used for storing electric energy at one time for use at another. Passing current through a discharged storage cell in the reverse direction causes chemical changes to take place which restore the cell to its original charged condition. This is called reversibility. The primary cell is not reversible to any marked extent.

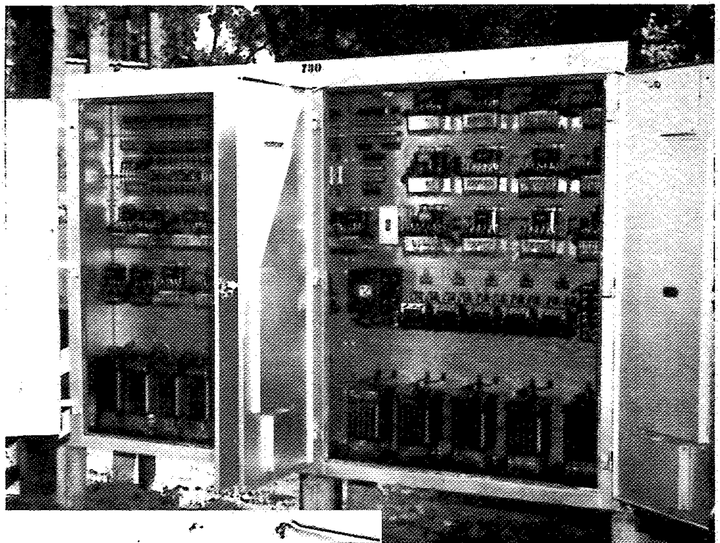

Figure 1203 (above). Lead-acid storage cells, copper-oxide rectifiers, and Type K relays at a highway crossing protection location.

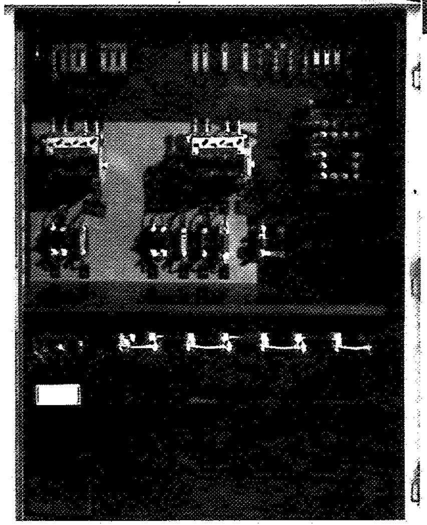

Figure 1204 (left). Nickel-iron-alkaline storage cells, copper-oxide rectifiers, and transformer.

Lead-acid cells are made in many sizes, but the voltage of a cell is the same whatever the size. Only the ampere-hour capacity is increased by increasing the size and number of plates, the same as in primary cells. Lead-acid cells are usually rated on the amount of current that they will deliver in 8 hours. An 80 ampere-hour cell will deliver 10 amperes for eight hours. Such a cell will deliver fewer ampere-hours when discharged in 5 hours, and the total capacity in ampere-hours will be greater if the discharge rate is less. This is the same as in primary cells.

Low temperature reduces the ampere-hour capacity of a storage cell. At 0° F., you would get only 45% of what you would get at 77° F. For example, a 120 ampere-hour battery would give you only around 54 ampere-hours at 0° F.

The electrolyte is diluted sulphuric acid with a specific gravity of from 1.210 to 1.220 (see maker's specifications). In a fully charged cell, the specific gravity varies from 1.215 to 1.300 at 77° F. A discharged cell reads about 1.140 at same temperature.

Voltage of a fully charged cell is 2 volts. On trickle charge, voltage is 2.15 to 2.2. A discharged cell reads 1.8 volts.

When charging lead-acid cells, it is necessary to put in considerably more energy than can be taken out. It is best not to discharge them too low or they will be too badly sulphated. When cells are discharged, the sulphate in the electrolyte is taken up by the plates, and when they are charged this sulphate is driven out again into the electrolyte. This makes the electrolyte heavier when the cells are fully charged and becomes thereby a means for telling when the cells are fully charged.

When cells are left standing, the charge gradually leaks off, and so it is good practice to keep a very small current flowing into them all the time to make up for this leakage. This is called trickle charging. When cells are used very little, or when it is not convenient to charge them at regular intervals, they may be given a similar charge, large enough to supply the current used as well as the leakage. This method, called a floating charge, is quite common in signal practice.

NICKEL-IRON-ALKALINE STORAGE CELLS

This cell is radically different from the lead-acid cell. It consists essentially of positive and negative plates, grid separators, a container, and electrolyte. The positive plates consist of perforated nickel plated steel tubes in which are placed nickel hydrate and flake nickel in alternate layers. The negative plates consist of perforated steel pockets which are made from nickel-plated cold-rolled steel strips. The strips are folded into a rectangular pocket and loaded with an iron oxide.

The cell containers are made of nickel plated steel or monel metal. The electrolyte is a solution of caustic potash and lithia in pure water. The normal specific gravity is approximately 1.200. The voltage of a fully charged cell is 1.2 volts and of a discharged cell one volt. The trickle charged voltage is 1.5 volts. The capacity of these cells is generally rated in ampere-hours at the 5-hour rate of discharge. The internal resistance is approximately 2 to 3 times that of lead cells.

This cell also shows a loss of capacity at low temperatures. It has a critical temperature which varies with the rate of discharge. Below this critical temperature, the output is very small. At the normal rate of discharge, the critical temperature is in the neighborhood of 32° F. For rates of discharge in excess of normal it is higher, and at small rates it is lower than this.

The manufacturers recommend that the nickel-iron cell should not be subjected to temperatures below 0° F., since lower temperatures may damage the cell sufficiently to permanently reduce its rated ampere-hour output at the standard temperature of 77° F.

The specific gravity of the solution changes very little from charge to discharge and therefore the capacity cannot be determined by reading the gravity. In order to determine the amount of charge that is left in a cell, it is necessary to place a resistance across the terminals and measure its voltage when delivering a certain current (see maker's recommendations).

NICKEL-CADMIUM STORAGE CELLS

The active material of the positive plate consists of nickel hydroxide and specially treated graphite. The active material of the negative plate consists of a mixture of oxides of cadmium and iron.

The electrolyte is a solution of pure caustic potash in distilled water. Normal specific gravity is 1.190. Voltage of a fully charged cell is 1.21 volts; of a discharged cell, one volt; and on trickle charge, 1.3 to 1.45 volts. The makers claim that this cell can be successfully operated at very low temperatures, and that at minus 40° F. the electrolyte forms a slush. The capacity obtained at the low temperatures is less than that at the standard temperature of 77° F. The percentage of ampere-hour output at low temperature is about the same as that of a lead-acid cell.

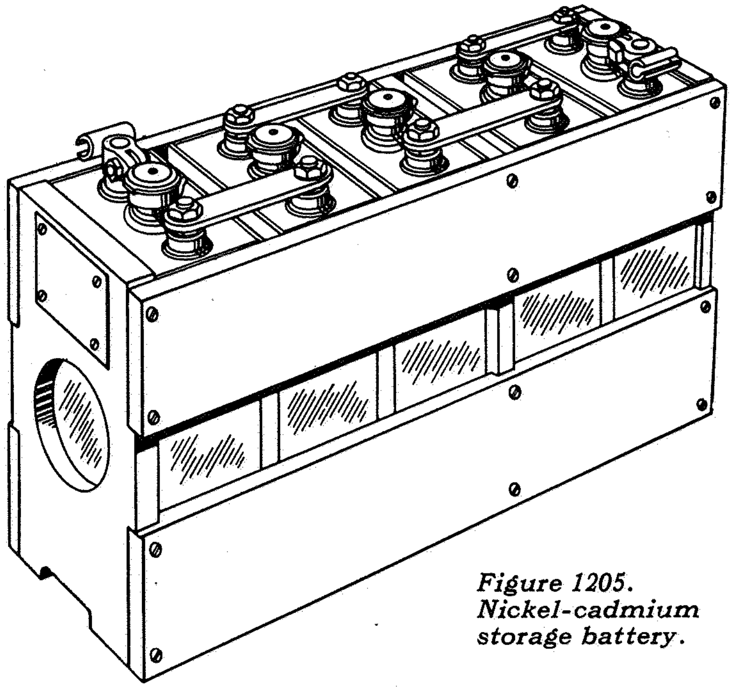

Figure 1205.
Nickel-cadmium storage battery.

The voltage obtained with this cell is similar to that of the nickel-iron cell. It has, however, a much lower internal resistance than the nickel-iron cell so that it compares more with the lead-acid cell in this respect. This means that the voltage drop at high current rates will be less than that of a nickel-iron cell.

BATTERY CHARGERS

GENERAL

In modern signal systems, battery chargers are most commonly of the dry plate type, such as the copper-oxide rectifiers described herein. Other battery charging devices that have been used include motor-generator sets, mercury arc rectifiers, and mechanical or vibrating-armature devices.

COPPER-OXIDE RECTIFIERS

When a coating of copper oxide has been formed on one face of a copper disc by special heat treatment, current flows more readily from the copper oxide to the copper than in the opposite direction. Each coated disc thus acts as an efficient electrical valve which allows current to flow in one direction and prevents its flow in the opposite direction. The valve action or rectification takes place at the junction of the copper and copper oxide. Numerous tests in laboratory and field show conclusively that this action is entirely electronic without any chemical action or decomposition of the rectifier elements.

Each rectifier unit, Figure 1206, comprises copper-oxide discs or washers, lead washers, brass radiating washers or cooling fins, and spacer and insulating washers assembled on an insulating tube over a bolt. The number of copper-oxide discs and their connection in series or multiple depend upon the output voltage and current for which a particular rectifier is designed.

A half-wave rectifier, Figure 1207, prevents the flow of current in one direction so that current from only one half of the a-c. wave flows through the load.

In a full-wave rectifier, Figure 1208, the flow of current is directed by the valve action of four rectifying discs connected in a Wheatstone-bridge circuit so that current from both halves

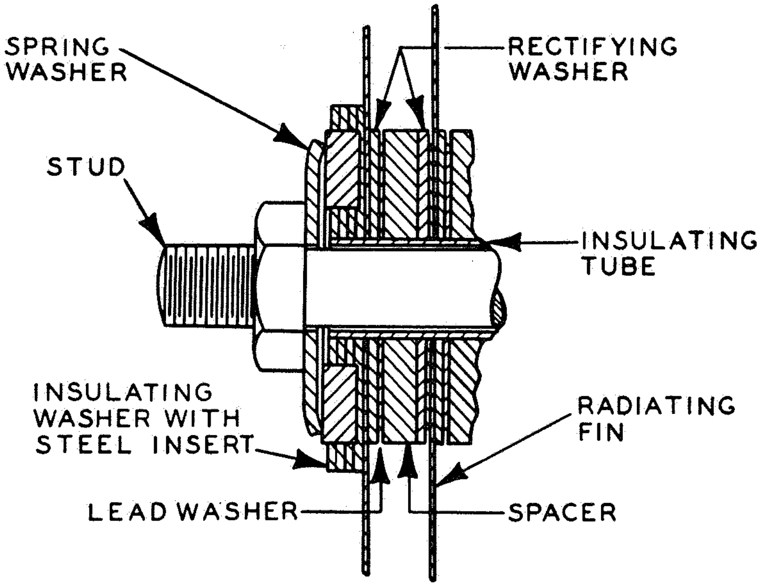
SPRING WASHER
STUD
RECTIFYING WASHER
INSULATING TUBE
INSULATING WASHER WITH STEEL INSERT
RADIATING FIN
LEAD WASHER
SPACER

Figure 1206. Cutaway of part of a copper-oxide rectifier unit.

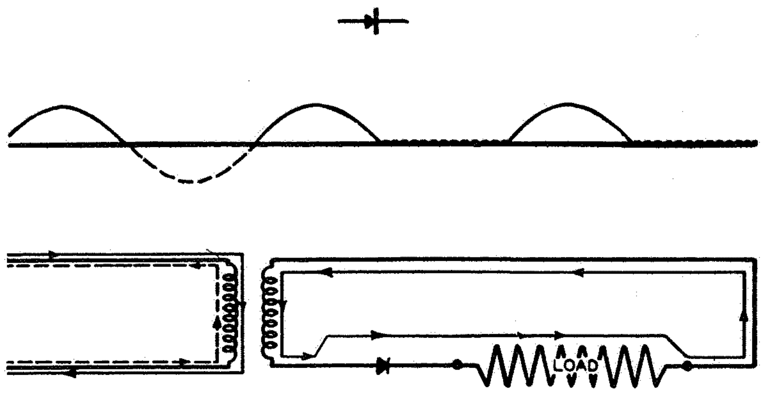

Figure 1207. Current flow through half-wave rectifier.

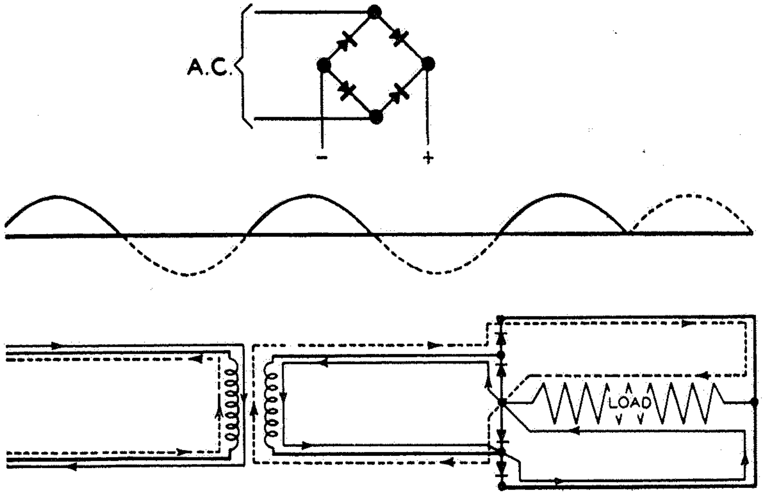

Figure 1208. Current flow through full-wave rectifier.

of the a-c. wave flows through the load in the same direction.

Copper-oxide rectifiers, generally used for charging storage batteries, can also be used for operating d-c. devices directly from a-c. lines and as snubbing rectifiers. Other materials, selenium for example, are also used in disc-type dry rectifiers. The basic valve action principle is the same.

Automatic Rectifiers

The automatic rectifier is usually used in multiple with primary battery to assume the major portion of the direct-current ampere output required by the load, the remaining small drain on the battery being sufficient to keep the primary battery in active condition. The design of the transformer used in the assembly is such as to cause the rectifier to automatically assume practically all of an increasing load current within the rated current limits of the rectifier.

The taps on the transformer, or a combination of transformer taps and sliding core, permit adjustment to be made so as to obtain the desired division of load between the battery and the automatic rectifier.

Two-Rate Charge Control

Figure 1209 shows a circuit designed to start a high-rate charge when a load is thrown on the battery. As the battery approaches its fully charged condition, the two-rate charge control relay, a relay especially developed for this purpose, picks up and changes the high rate to a low rate. Resistor R is to be added if the transformer does not give required degree of adjustment for high-rate charge.

TRANSFORMERS

A transformer is a device for raising or lowering the voltage of an a-c. circuit. It "transforms" one voltage into another. It consists, in its simplest form, of two windings on an iron core. The purpose of the iron core is to ensure that the magnetic field set up about the primary coil will flow through the secondary coil without loss. What few lines of force do not link primary and secondary are called leakage lines, and the inductance associated with them is called leakage inductance.

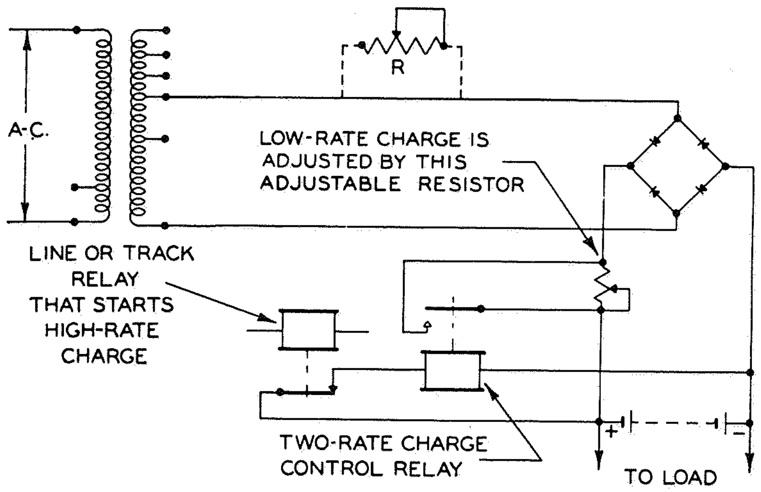
A-C.
R
LOW-RATE CHARGE IS ADJUSTED BY THIS ADJUSTABLE RESISTOR
LINE OR TRACK RELAY THAT STARTS HIGH-RATE CHARGE
TWO-RATE CHARGE CONTROL RELAY
+
−
TO LOAD

Figure 1209. Two-rate charge control circuit.

The primary is attached to an a-c. line, the secondary to the load, which may be a house lighting circuit, a motor, or any other device which requires electricity.

The lines of force from the continually changing alternating current in the primary flow through the secondary and induce voltages in it. The relation between the primary and secondary voltages is simple and definite—it depends upon the relative number of turns. If there are twice as many secondary turns as there are primary turns, the voltage developed across the secondary terminals will be double that across the primary.

Transformers used in signal work may be either the dry type, self-cooled; or oil-immersed, self-cooled, depending on the capacity of the transformer. Dry type transformers are generally used with primary voltages up to 600 volts. Above 600 volts, oil-immersed transformers are usually used.

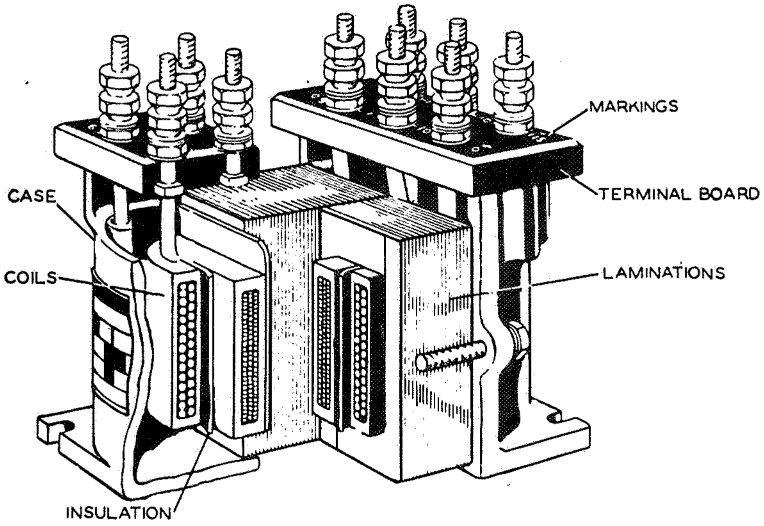

Figure 1210. Cutaway view of air-cooled transformer.

EFFECTS OF DIFFERENT FREQUENCIES

The lower the frequency the larger must be the transformer in order to deliver a given output without overheating. The frequencies generally used in signal work are 25, 60, and 100 cycles.

A transformer designed for a certain work at 25 cycles would perform the same work on a 60-cycle transmission line with less heat than on the 25-cycle transmission line. The same applies to a 60-cycle transformer used on a 100-cycle transmission line. A 25-cycle transformer connected to a 60-cycle transmission line would have its coils cut by the magnetic flux at more than twice the rate they would be cut by a 25-cycle transmission, therefore requiring less lines of force to perform the function of sustaining the voltage in the coils and a smaller iron core to accommodate them. It is therefore evident that transformers designed for a certain frequency should not be used on lines having a lower frequency, as excessive current will flow in the primary coil, thus causing overheating.

VOLTAGES AND POLARITY

Figure 1211 shows how the terminal board on a typical G-R-S transformer is marked. This particular transformer has a primary and two secondary windings. The primary has a tap at 10 volts. The upper secondary has taps for 1, 2, or 3 volts. The lower secondary has taps for 4, 8, or 12 volts. The dotted line shows how the two secondaries may be connected in series to get a 15-volt secondary. Note that plus is connected to minus in the usual way.

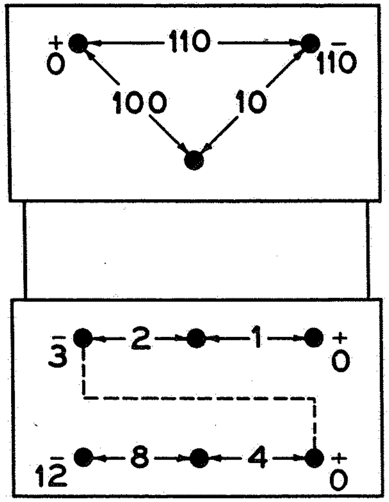

Figure 1211. Typical transformer voltage diagram.

MAIN OFFICE AND PLANT
BOX 600 ROCHESTER NY 14602 Phone: 716 · 436-2020 Cable: GENRASIG (ROCHESTER NY)
Telex: 978317

ATLANTA OFFICE
3379 PEACHTREE ROAD NE ATLANTA GA 30326 Phone: 404 · 233-7373

BOSTON OFFICE
1029 STATLER OFFICE BUILDING BOSTON MA 02116 Phone: 617 · 426-1003

CHICAGO OFFICE
PRUDENTIAL PLAZA CHICAGO IL 60601 Phone: 312 · 467-1221

MONTREAL OFFICE
SUITE 1731 1 PLACE VILLE MARIE MONTREAL QUEBEC H3B 2C1
Phone: 514 · 861-1536

NEW YORK OFFICE
230 PARK AVENUE NEW YORK NY 10017 Phone: 212 · 689-7533

OAKLAND OFFICE
UNITED CALIFORNIA BANK BUILDING SUITE 915 1330 BROADWAY OAKLAND CA 94612
Phone: 415·893-3100

ST. LOUIS OFFICE
LACLEDE GAS BUILDING 720 OLIVE STREET ST. LOUIS MO 63101
Phone: 314 · 621-4696

ST. PAUL OFFICE
NORTHWESTERN NATIONAL BANK BUILDING SUITE 1380 55 E 5TH STREET ST.PAUL MN 55101
Phone: 612 · 227-9268

WASHINGTON OFFICE
490 L'ENFANT PLAZA EAST S.W. WASHINGTON DC 20024 Phone: 202 · 554-5403

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